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ADVANCED MANUFACTURING (AMFG)

AMFG401. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

AMFG498. SPECIAL TOPICS IN ADVANCED MANUFACTURING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

AMFG501. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

AMFG598. SPECIAL TOPICS IN ADVANCED MANUFACTURING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

AIR FORCE (AFGN)

AFGN101. FOUNDATIONS OF THE UNITED STATES AIR FORCE. 1.5 Semester Hr.
Two semesters, 1.5 hours per semester. This survey course briefly covers topics relating to the Air Force and defense. It focuses on the structure and missions of Air Force organizations, officership and professionalism. It is also a good introduction into the use of communication skills. Weekly Leadership Lab for this course (to be taken in conjunction with AS 101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN102. FOUNDATIONS OF THE UNITED STATES AIR FORCE. 1.5 Semester Hr.
Two semesters, 1.5 hours per semester. This survey course briefly covers topics relating to the Air Force and defense. It focuses on the structure and missions of Air Force organizations, officership and professionalism. It is also a good introduction into the use of communication skills. Weekly Leadership Lab for this course (to be taken in conjunction with AS 101 and 102) is a weekly laboratory that touches on the topics of Air Force customs and courtesies, health and physical fitness, and drill and ceremonies.

AFGN201. THE EVOLUTION OF USAF AIR AND SPACE POWER. 1.5 Semester Hr.
Two semesters, 1.5 hours per semester. This survey course is concerned with the beginnings of manned flight and the development of aerospace power in the United States, including the employment of air power in WWI, WWII, Korea, Vietnam, the Gulf War and the peaceful employment of U.S. air power in civic actions, scientific missions and support of space exploration. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN202. THE EVOLUTION OF USAF AIR AND SPACE POWER. 1.5 Semester Hr.
Two semesters, 1.5 hours per semester. This survey course is concerned with the beginnings of manned flight and the development of aerospace power in the United States, including the employment of air power in WWI, WWII, Korea, Vietnam, the Gulf War and the peaceful employment of U.S. air power in civic actions, scientific missions and support of space exploration. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 201 and 202) provides you with the opportunity to demonstrate fundamental management skills and prepares you for Field Training.

AFGN301. AIR FORCE LEADERHIP STUDIES. 3.5 Semester Hrs.
Two semesters, 3.5 hours per semester. This course is a study in the anatomy of leadership, the need for quality and management leadership, the role of discipline in leadership situations and the variables affecting leadership. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts. Deal with actual problems and complete projects associated with planning and managing the Leadership Laboratory. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN302. AIR FORCE LEADERHIP STUDIES. 3.5 Semester Hrs.
Two semesters, 3.5 hours per semester. This course is a study in the anatomy of leadership, the need for quality and management leadership, the role of discipline in leadership situations and the variables affecting leadership. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts. Deal with actual problems and complete projects associated with planning and managing the Leadership Laboratory. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 301 and 302) provides you the opportunity to develop your fundamental management skills while planning and conducting cadet activities.

AFGN401. NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY. 3.5 Semester Hrs.
Two semesters, 3.5 hours per semester. Learn about the role of the professional military leader in a democratic society; societal attitudes toward the armed forces; the requisites for maintaining adequate national defense structure; the impact of technological and international developments on strategic preparedness and the overall policy-making process; and military law. In addition, you will study topics that will prepare you for your first active-duty assignment as an officer in the Air Force. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

AFGN402. NATIONAL SECURITY AFFAIRS AND PREPARATION FOR ACTIVE DUTY. 3.5 Semester Hrs.
Two semesters, 3.5 hours per semester. Learn about the role of the professional military leader in a democratic society; societal attitudes toward the armed forces; the requisites for maintaining adequate national defense structure; the impact of technological and international developments on strategic preparedness and the overall policy-making process; and military law. In addition, you will study topics that will prepare you for your first active-duty assignment as an officer in the Air Force. Weekly Leadership Laboratory (LLAB) for this course (to be taken in conjunction with AS 401 and 402) provides you with the opportunity to use your leadership skills in planning and conducting cadet activities. It prepares you for commissioning and entry into the active-duty Air Force.

CHEMICAL AND BIOLOGICAL ENGINEERING (CBEN)

CBEN110. FUNDAMENTALS OF BIOLOGY I. 4.0 Semester Hrs.
Equivalent with BELS311,BIOL110,
(I, II) Fundamentals of Biology with Laboratory I. This course will emphasize the fundamental concepts of biology and use illustrative examples and laboratory investigations that highlight the interface of biology with engineering. The focus will be on (1) the scientific method; (2) structural, molecular, and energetic basis of cellular activities; (3) mechanisms of storage and transfer of genetic information in biological organisms; (4) a laboratory 'toolbox' that will carry them forward in their laboratory-based courses. This core course in biology will be interdisciplinary in nature and will incorporate the major themes and mission of this school - earth, energy, and the environment. Lecture Hours: 3; Lab Hours: 3; Semester Hours: 4.

CBEN120. FUNDAMENTALS OF BIOLOGY II. 4.0 Semester Hrs.
Equivalent with BELS313,CBEN323,
This is the continuation of Fundamentals of Biology I. Emphasis in the second semester is placed on an examination of organisms as the products of evolution and the diversity of life forms. Special attention will be given to how form fits function in animals and plants and the potential for biomimetic applications. Prerequisite: CBEN110. Fundamentals of Biology I or equivalent. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CBEN198. SPECIAL TOPICS. 6.0 Semester Hrs.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN199. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN200. COMPUTATIONAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN200,
(II) Fundamentals of mathematical methods and computer programming as applied to the solution of chemical engineering problems. Introduction to computational methods and algorithm development and implementation. Prerequisites: MATH112. 3 hours lecture; 3 semester hours.

CBEN201. MATERIAL AND ENERGY BALANCES. 3.0 Semester Hrs.
Equivalent with CHEN201,
(II) Introduction to the formulation and solution of material and energy balances on chemical processes. Establishes the engineering approach to problem solving, the relations between known and unknown process variables, and appropriate computational methods. Prerequisites: CHGN122. Corequisites: CBEN210 (or equivalent); CBEN202, MATH213, MATH225. 3 hours lecture; 3 semester hours.

CBEN202. CHEMICAL PROCESS PRINCIPLES LABORATORY. 1.0 Semester Hr.
Equivalent with CHEN202,
(II) Laboratory measurements dealing with the first and second laws of thermodynamics, calculation and analysis of experimental results, professional report writing. Introduction to computer-aided process simulation. Corequisites: CBEN210, CBEN201, MATH225, EDNS251. 3 hours lab; 1 semester hour.

CBEN210. INTRO TO THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with DCGN210,
(I, II) Introduction to the fundamental principles of classical engineering thermodynamics. Application of mass and energy balances to closed and open systems including systems undergoing transient processes. Entropy generation and the second law of thermodynamics for closed and open systems. Introduction to phase equilibrium and chemical reaction equilibria. Ideal solution behavior. May not also receive credit for CHGN209, MEGN361, or GEGN330. Prerequisites: CHGN121, CHGN122, MATH111. Co-requisites: MATH112, PHGN100. 3 hours lecture; 3 semester hours.

CBEN250. INTRODUCTION TO CHEMICAL ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.
Equivalent with CHEN250,
Introduction to chemical process industries and how analysis and design concepts guide the development of new processes and products. Use of simple mathematical models to describe the performance of common process building blocks including pumps, heat exchangers, chemical reactors, and separators. Prerequisites: Concurrent enrollment in CBEN210. 3 hours lecture; 3 semester hours.

CBEN298. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN299. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN304. ANATOMY AND PHYSIOLOGY. 3.0 Semester Hrs.
Equivalent with BELS404,CBEN404,
(II) This course will cover the basics of human anatomy and physiology of the cardiovascular system and blood, the immune system, the respiratory system, the digestive system, the endocrine system, the urinary system and the reproductive system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Prerequisite: General Biology I. 3 hours lecture; 3 semester hours.

CBEN305. ANATOMY AND PHYSIOLOGY LAB. 1.0 Semester Hr.
Equivalent with BELS405,CBEN405,
(II) In this course we explore the basic concepts of human anatomy and physiology using simulations of the physiology and a virtual human dissector program. These are supplemented as needed with animations, pictures and movies of cadaver dissection to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology. Corequisite: CBEN404. 3 lab hours, 1 semester hour.

CBEN306. ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN. 3.0 Semester Hrs.
Equivalent with BELS406,CBEN406,
(I) This course will cover the basics of human anatomy and physiology of the tissues, skeletal system, muscular system, central nervous system and peripheral nervous system. We will discuss the gross and microscopic anatomy and the physiology of these major systems. Where possible, we will integrate discussions of disease processes and introduce biomedical engineering concepts and problems. Prerequisite: General Biology I. 3 hour lecture; 3 semester hours.

CBEN307. FLUID MECHANICS. 3.0 Semester Hrs.
Equivalent with CHEN307,
(I) This course covers theory and application of momentum transfer and fluid flow. Fundamentals of microscopic phenomena and application to macroscopic systems are addressed. Course work also includes computational fluid dynamics. Prerequisites: MATH225, grade of C- or better in CBEN201. 3 hours lecture; 3 semester hours.

CBEN308. HEAT TRANSFER. 3.0 Semester Hrs.
Equivalent with CHEN308,
(II) This course covers theory and applications of energy transfer: conduction, convection, and radiation. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat transfer problems. Prerequisites: MATH225, grade of C- or better in CBEN307. 3 hours lecture; 3 semester hours.

CBEN309. ANATOMY AND PHYSIOLOGY: BONE, MUSCLE, AND BRAIN LABORATORY. 1.0 Semester Hr.
Equivalent with BELS407,CBEN407,
(I) In this course we explore the basic concepts of human anatomy and physiology of the tissue types, skeletal system, muscular system, and nervous system using anatomical models and medical tissue microscope slides. These are supplemented as needed with pictures, chalk talks, handouts, ultrasound for muscle and skeleton, and EEG recording of brain waves to provide the student with a practical experience discovering principles and structures associated with the anatomy and physiology and to reinforce the material from the lecture course. Prerequisite: General Biology 1 [BIOL110]. Co-requisites: must either have taken or currently taking Anatomy and Physiology BMB [CBEN406]. 3 hour lab; 1 semester hour.

CBEN310. INTRODUCTION TO BIOMEDICAL ENGINEERING. 3.0 Semester Hrs.
(I) Introduction to the field of Biomedical Engineering including biomolecular, cellular, and physiological principles, and areas of specialty including biomolecular engineering, biomaterials, biomechanics, bioinstrumentation and bioimaging. Prerequisites: BIOL110 and (CBEN210 or CHGN209 or MEGN361). 3 hours lecture, 3 semester hours.

CBEN311. INTRODUCTION TO NEUROSCIENCE. 3.0 Semester Hrs.
(I, II) This course is the general overview of brain anatomy, physiology, and function. It includes perception, motor, language, behavior, and executive function. This course will review what happens with injury and abnormalities of thought. It will discuss the overview of brain development throughout one?s lifespan. Prerequisites: BIOL110, CHGN121, CHGN122, PHGN100, PHGN200. 3 hours lecture; 3 semester hours.

CBEN312. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Equivalent with CHEN312,
(S) Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. Prerequisites: CBEN201, CBEN202, CBEN307, CBEN308, CBEN357, CBEN375. 9 hours lab; 3 semester hours.

CBEN313. UNIT OPERATIONS LABORATORY. 3.0 Semester Hrs.
Equivalent with CHEN313,
(S) Unit Operations Laboratory. This course covers principles of mass, energy, and momentum transport as applied to laboratory-scale processing equipment. Written and oral communications skills, teamwork, and critical thinking are emphasized. Prerequisites: CBEN201, CBEN202, CBEN307, CBEN308, CBEN357, CBEN375. 9 hours lab; 3 semester hours.

CBEN314. CHEMICAL ENGINEERING HEAT AND MASS TRANSFER. 4.0 Semester Hrs.
(II) This course covers theory and applications of energy transfer: conduction, convection, and radiation and mass transfer: diffusion and convection. Fundamentals of microscopic phenomena and their application to macroscopic systems are addressed. Course work also includes application of relevant numerical methods to solve heat and mass transfer problems. Prerequisites: MATH225, CBEN 200, grade of C- or better in CBEN307. 4 hours lecture; 4 semester hours.

CBEN315. INTRODUCTION TO ELECTROCHEMICAL ENGINEERING. 3.0 Semester Hrs.
(II) Introduction to the field of Electrochemical Engineering including basic electrochemical principles, electrode kinetics, ionic conduction, as applied to common devices such as fuel cells, electrolyzers, redox flow cells and batteries. Prerequisites: CBEN210. 3 hours lecture; 3 semester hours.

CBEN320. CELL BIOLOGY AND PHYSIOLOGY. 3.0 Semester Hrs.
Equivalent with BELS402,CBEN410,ESGN402,
(II) An introduction to the morphological, biochemical, and biophysical properties of cells and their significance in the life processes. Prerequisite: General Biology I or equivalent. 3 hours lecture; 3 semester hours.

CBEN321. INTRO TO GENETICS. 4.0 Semester Hrs.
Equivalent with BELS321,ESGN321,
(II) A study of the mechanisms by which biological information is encoded, stored, and transmitted, including Mendelian genetics, molecular genetics, chromosome structure and rearrangement, cytogenetics, and population genetics. Prerequisite: General biology I or equivalent. 3 hours lecture, 3 hours laboratory; 4 semester hours.

CBEN322. BIOLOGICAL PSYCHOLOGY. 3.0 Semester Hrs.
(II) This course relates the hard sciences of the brain and neuroscience to the psychology of human behavior. It covers such topics as decision making, learning, the brain's anatomy and physiology, psychopathology, addiction, the senses, sexuality, and brainwashing. It addresses the topics covered on the psychology section of the MCAT examination. Prerequisites: CBEN110, CHGN122, PHGN200. 3 hours lecture; 3 semester hours.

CBEN323. GENERAL BIOLOGY II LABORATORY. 1.0 Semester Hr.
Equivalent with BELS313,CBEN120,ESGN313,
(I, II) This Course provides students with laboratory exercises that complement lectures given in CBEN303, the second semester introductory course in Biology. Emphasis is placed on an examination of organisms as the products of evolution. The diversity of life forms will be explored. Special attention will be given to the vertebrate body (organs, tissues and systems) and how it functions. Co-requisite or Prerequisite: CBEN303 or equivalent. 3 hours laboratory; 1 semester hour.

CBEN324. INTRODUCTION TO BREWING SCIENCE. 3.0 Semester Hrs.
(II) Introduction to the field of Brewing Science including an overview of ingredients and the brewing process, the biochemistry of brewing, commercial brewing, quality control, and the economics of the brewing industry. Students will malt grain, brew their own beer, and analyze with modern analytical equipment. Prerequisites: CBEN110; Student must be at least 21 years of age at beginning of semester. 2 hours lecture; 3 hours lab; 3 semester hours.

CBEN325. MCAT REVIEW. 3.0 Semester Hrs.
(II) The MCAT Review course is specifically for preparation of the Medical College Admissions Test [MCAT]. It will look at test taking skills, the information required to study for the MCAT, and will go over in detail the psychology information and the critical analysis and reading skills sections of the exam as well as doing practice exams. Prerequisites: CBEN110, PHGN200, CHGN222. Co-requisites: CBEN120. 3 hours lecture; 3 semester hours.

CBEN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
Equivalent with CHEN340,
Cooperative work/education experience involving employment of a chemical engineering nature in an internship spanning at least one academic semester. Prerequisite: none. 1 to 3 semester hours. Repeatable to a maximum of 6 hours.

CBEN350. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with CHEN350,
Scholarly research of an independent nature. Prerequisite: Junior standing. 1 to 3 semester hours.

CBEN351. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with CHEN351,
Scholarly research of an independent nature. Prerequisite: junior standing. 1 to 3 semester hours.

CBEN357. CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with CHEN357,
(I) Introduction to non-ideal behavior in thermodynamic systems and their applications. Phase and reaction equilibria are emphasized. Relevant aspects of computer-aided process simulation are incorporated. Prerequisites: CBEN210 (or equivalent), MATH225, grade of C- or better in CBEN201. 3 hours lecture; 3 semester hours.

CBEN358. CHEMICAL ENGINEERING THERMODYNAMICS LABORATORY. 1.0 Semester Hr.
Equivalent with CHEN358,
(I) This course includes hands-on laboratory measurements of physical data from experiments based on the principles of chemical engineering thermodynamics. Methods and concepts explored include calculation and analysis of physical properties, phase equilibria, and reaction equilibria and the application of these concepts in chemical engineering. Prerequisites: CBEN200 and CBEN210. 3 hours lab; 1 semester hour.

CBEN360. BIOPROCESS ENGINEERING. 3.0 Semester Hrs.
(I) The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. Computer-aided process simulation is incorporated. Prerequisites: CHGN428, CBEN201, CBEN358. 2 hours lecture; 3 hours lab; 3 semester hours.

CBEN365. INTRODUCTION TO CHEMICAL ENGINEERING PRACTICE. 3.0 Semester Hrs.
(I) Builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving approached in an integrated teamwork environment, and initial technical content specific to the Chemical Engineering degree program to solve a range of chemical process engineering problems. Technical content necessary for process analysis and design activity is presented. This course emphasizes steady-state design in areas such as fuels, food sciences, chemicals, and pharmaceuticals, wherein creative and critical thinking skills are necessary. Projects may involve computer-based optimization to obtain a solution. Prerequisites: EDNS151 or EDNS155, CBEN 200, CBEN201. 3 hours lecture; 3 semester hours.

CBEN368. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.
Equivalent with CHEN368,
(I, II) Introduction to Undergraduate Research. This course introduces research methods and provides a survey of the various fields in which CBE faculty conduct research. Topics such as how to conduct literature searches, critically reading and analyzing research articles, ethics, lab safety, and how to write papers are addressed. Prerequisites: None. 1 hour lecture; 1 semester hour.

CBEN375. CHEMICAL ENGINEERING SEPARATIONS. 3.0 Semester Hrs.
Equivalent with CHEN375,
(II) This course covers fundamentals of stage-wise and diffusional mass transport with applications to chemical engineering systems and processes. Relevant aspects of computer-aided process simulation and computational methods are incorporated. Prerequisites: grade of C- or better in CBEN357. 3 hours lecture; 3 semester hours.

CBEN398. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN399. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN401. PROCESS OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with CHEN401,
(I, II, S) This course introduces skills and knowledge required to develop conceptual designs of new processes and tools to analyze troubleshoot, and optimize existing processes. Prerequisites: CBEN201, CBEN308, CBEN307, CBEN357, CBEN375. 3 hours lecture; 3 semester hours.

CBEN402. CHEMICAL ENGINEERING DESIGN. 3.0 Semester Hrs.
Equivalent with CHEN402,
(II) This course covers simulation, synthesis, analysis, evaluation, as well as costing and economic evaluation of chemical processes. Computer-aided process simulation to plant and process design is applied. Prerequisites: CBEN307, CBEN308, CBEN357, CBEN358, CBEN375. Co-requisites: CBEN418, EBGN321. 3 hours lecture; 3 semester hours.

CBEN403. PROCESS DYNAMICS AND CONTROL. 3.0 Semester Hrs.
Equivalent with CHEN403,
(II) Mathematical modeling and analysis of transient systems. Applications of control theory to response of dynamic chemical engineering systems and processes. 3 hours lecture, 3 semester hours. Prerequisites: CBEN201, CBEN307, CBEN308, CBEN375, MATH225.

CBEN408. NATURAL GAS PROCESSING. 3.0 Semester Hrs.
Equivalent with CHEN408,
(II) Application of chemical engineering principles to the processing of natural gas. Emphasis on using thermodynamics and mass transfer operations to analyze existing plants. Relevant aspects of computer-aided process simulation. Prerequisites: CHGN221, CBEN201, CBEN307, CBEN308, CBEN357, CBEN375. 3 hours lecture, 3 semester hours.

CBEN409. PETROLEUM PROCESSES. 3.0 Semester Hrs.
Equivalent with CHEN409,
(I) Application of chemical engineering principles to petroleum refining. Thermodynamics and reaction engineering of complex hydro carbon systems. Relevant aspects of computer-aided process simulation for complex mixtures. Prerequisite: CHGN221, CBEN201, CBEN357, CBEN375. 3 hours lecture; 3 semester hours.

CBEN411. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.
Equivalent with CBEN511,
(II) This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. Prerequisites: CBEN110, CBEN120, CHGN221, CHGN222, PHGN100, PHGN200. 3 hours lecture, 3 semester hours.

CBEN412. INTRODUCTION TO PHARMACOLOGY. 3.0 Semester Hrs.
(II) This course introduces the concepts of pharmacokinetics and biopharmaceuticals. It will discuss the delivery systems for pharmaceuticals and how they change with disease states. It will cover the modeling of drug delivery, absorption, excretion, and accumulation. The course will cover the different modeling systems for drug delivery and transport. Prerequisites: CBEN110, CBEN120, CHGN121, CHGN122. 3 hours lecture; 3 semester hours.

CBEN413. INTRODUCTION TO BIOELECTRICITY. 3.0 Semester Hrs.
(II) This course examines the bioelectric implications of the brain, heart, and muscles from a biomedical engineering view point. The course covers human brain, heart, and muscle anatomy as well as the devices currently in use to overcome abnormalities in function. Prerequisite: CBEN 110, CBEN 120. 3 hours lecture; 3 semester hours.

CBEN414. CHEMICAL PROCESS SAFETY. 1.0 Semester Hr.
(I) This course considers all aspects of chemical process safety and loss prevention. Students are trained for the identification of potential hazards and hazardous conditions associated with the processes and equipment involved in the chemical process industries, and methods of predicting the possible severity of these hazards and presenting, controlling or mitigating them. Quantitative engineering analysis training delivered by each of the CHEN core courses is applied: applications of mass and energy balances, fluid mechanics of liquid, gas, and two-phase flows, heat transfer, the conservation of energy, mass transfer, diffusion and dispersion under highly variable conditions, reaction kinetics, process control, and statistical analysis. Prerequisite: CBEN375. Corequisite: CBEN418. 1 hour lecture; 1 semester hour.

CBEN415. POLYMER SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with BELS415,CHEN415,CHGN430,MLGN530,
Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. Prerequisite: CHGN221, MATH225, CBEN357. 3 hours lecture; 3 semester hours.

CBEN416. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN416,
Polymer fluid mechanics, polymer rheological response, and polymer shape forming. Definition and measure ment of material properties. Interrelationships between response functions and correlation of data and material response. Theoretical approaches for prediction of polymer properties. Processing operations for polymeric materials; melt and flow instabilities. Prerequisite: CBEN307, MATH225. 3 hours lecture; 3 semester hours.

CBEN418. KINETICS AND REACTION ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN418,
(I) (WI) This course emphasizes applications of the fundamentals of thermodynamics, physical chemistry, organic chemistry, and material and energy balances to the engineering of reactive processes. Key topics include reactor design, acquisition and analysis of rate data, and heterogeneous catalysis. Computational methods as related to reactor and reaction modeling are incorporated. Prerequisites: CBEN308, CBEN357, MATH225, CHGN221. Co-requisites: CHGN351. 3 hours lecture; 3 semester hours.

CBEN420. MATHEMATICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN420,
Formulation and solution of chemical engineering problems using numerical solution methods within the Excel and MathCAD environments. Setup and numerical solution of ordinary and partial differential equations for typical chemical engineering systems and transport processes. Prerequisite: MATH225, CHGN209 or CBEN210, CBEN307, CBEN357. 3 hours lecture; 3 semester hours.

CBEN422. CHEMICAL ENGINEERING FLOW ASSURANCE. 3.0 Semester Hrs.
(II) Chemical Engineering Flow Assurance will include the principles of the application of thermodynamics and mesocopic and microscopic tools that can be applied to the production of oil field fluids, including mitigation strategies for solids, including gas hydrates, waxes, and asphaltenes. Prerequisite: CBEN357. 3 hours lecture; 3 semester hours.

CBEN430. TRANSPORT PHENOMENA. 3.0 Semester Hrs.
Equivalent with CHEN430,
(I) This course covers theory and applications of momentum, energy, and mass transfer based on microscopic control volumes. Analytical and numerical solution methods are employed in this course. Prerequisites: CBEN307, CBEN308, CBEN357, CBEN375, MATH225. 3 hours lecture; 3 semester hours.

CBEN431. IMMUNOLOGY FOR ENGINEERS AND SCIENTISTS. 3.0 Semester Hrs.
Equivalent with BELS431,
(II) This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies, immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry.Prerequisites: General Biology [BIOL110] or equivalent. 3 Lecture hours, 3 semester hours.

CBEN432. TRANSPORT PHENOMENA IN BIOLOGICAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with BELS432,CHEN432,
The goal of this course is to develop and analyze models of biological transport and reaction processes. We will apply the principles of mass, momentum, and energy conservation to describe mechanisms of physiology and pathology. We will explore the applications of transport phenomena in the design of drug delivery systems, engineered tissues, and biomedical diagnostics with an emphasis on the barriers to molecular transport in cardiovascular disease and cancer. Prerequisites: CBEN430 or equivalent. 3 lecture hours, 3 credit hours.

CBEN435. INTERDISCIPLINARY MICROELECTRONICS. 3.0 Semester Hrs.
Equivalent with CHEN435,CHEN535,MLGN535,PHGN435,PHGN535,
(II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CBEN, MTGN, or EGGN. Due to lab, space the enrollment is limited to 20 students. 1.5 hours lecture, 4 hours lab; 3 semester hours.

CBEN440. MOLECULAR PERSPECTIVES IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN440,
Applications of statistical and quantum mechanics to understanding and prediction of equilibrium and transport properties and processes. Relations between microscopic properties of materials and systems to macroscopic behavior. Prerequisite: CBEN307, CBEN308, CBEN357, CBEN375, CHGN351 and CHGN353, CHGN221 and CHGN222, MATH225. 3 hours lecture; 3 semester hours.

CBEN450. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with CHEN450,
Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN451. HONORS UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with CHEN451,
Scholarly research of an independent nature. Prerequisite: senior standing. 1 to 3 semester hours.

CBEN454. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.
Equivalent with BELS454,
(II) In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. Prerequisites: General Biology [BIOL110]. 3 hour lecture; 3 semester hours.

CBEN460. BIOCHEMICAL PROCESS ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN460,
(I) The analysis and design of microbial reactions and biochemical unit operations, including processes used in conjunction with bioreactors, are investigated in this course. Industrial enzyme technologies are developed and explored. A strong focus is given to the basic processes for producing fermentation products and biofuels. Biochemical systems for organic oxidation and fermentation and inorganic oxidation and reduction are presented. Prerequisites: CBEN375, CHGN428, CHGN462. 3 hours lecture; 3 semester hours.

CBEN461. BIOCHEMICAL PROCESS ENGINEERING LABORATORY. 1.0 Semester Hr.
Equivalent with CHEN461,
(I) This course emphasizes bio-based product preparation, laboratory measurement, and calculation and analysis of bioprocesses including fermentation and bio-solids separations and their application to biochemical engineering. Computer-aided process simulation is incorporated. Prerequisites: CBEN375, CHGN428, CHGN462. Co-requisite: CBEN460, 3 hours laboratory, 1 semester hour.

CBEN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN469,EGGN469,MEGN469,MTGN469,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials-science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: MEGN361 or CBEN357 or MTGN351. 3 hours lecture; 3 semester hours.

CBEN470. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.
Equivalent with BELS470,CHEN470,
This course introduces the basic principles and applications of microfluidic systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Prerequisites: CBEN307 or MEGN351. 3 hours lecture; 3 semester hours.

CBEN472. INTRODUCTION TO ENERGY TECHNOLOGIES. 3.0 Semester Hrs.
Equivalent with CHEN472,
(II) In this course the student will gain an understanding about energy technologies including how they work, how they are quantitatively evaluated, what they cost, and what is their benefit or impact on the natural environment. There will be discussions about proposed energy systems and how they might become a part of the existing infrastructure. However, to truly understand the impact of proposed energy systems, the student must also have a grasp on the infrastructure of existing energy systems. Prerequisites: CBEN357 Chemical Engineering Thermodynamics (or equivalent). 3 lecture hours, 3 credit hours.

CBEN480. NATURAL GAS HYDRATES. 3.0 Semester Hrs.
Equivalent with CHEN480,
The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co-authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN498. SPECIAL TOPICS. 1-6 Semester Hr.
Topical courses in chemical engineering of special interest. Prerequisite: none; 1 to 6 semester hours. Repeatable for credit under different titles.

CBEN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects. Topics, content, and credit hours to be agreed upon by student and supervising faculty member. Prerequisite: none, submission of ?Independent Study? form to CSM Registrar. 1 to 6 semester hours. Repeatable for credit.

CBEN504. ADVANCED PROCESS ENGINEERING ECONOMICS. 3.0 Semester Hrs.
Equivalent with CHEN504,
Advanced engineering economic principles applied to original and alternate investments. Analysis of chemical and petroleum processes relative to marketing and return on investments. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN505. NUMERICAL METHODS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN505,
Engineering applications of numerical methods. Numerical integration, solution of algebraic equations, matrix 54 Colorado School of Mines Graduate Bulletin 2011 2012 algebra, ordinary differential equations, and special emphasis on partial differential equations. Emphasis on application of numerical methods to chemical engineering problems which cannot be solved by analytical methods. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN507. APPLIED MATHEMATICS IN CHEMICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with CHEN507,
(I, II) This course stresses the application of mathematics to problems drawn from chemical and biological engineering fundamentals such as thermodynamics, transport phenomena, and kinetics. Formulation and solution of ordinary and partial differential equations arising in chemical engineering or related processes or operations are discussed. Prerequisite: Undergraduate differential equations course; undergraduate chemical engineering courses covering reaction kinetics, and heat, mass and momentum transfer. 3 hours lecture; 3 semester hours.

CBEN509. ADVANCED CHEMICAL ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with CHEN509,
Extension and amplification of under graduate chemical engineering thermodynamics. Topics will include the laws of thermodynamics, thermodynamic properties of pure fluids and fluid mixtures, phase equilibria, and chemical reaction equilibria. Prerequisite: CBEN357 or equivalent. 3 hours lecture; 3 semester hours.

CBEN511. NEUROSCIENCE, MEMORY, AND LEARNING. 3.0 Semester Hrs.
Equivalent with CBEN411,
(II) This course relates the hard sciences of the brain and neuroscience to memory encoding and current learning theories. Successful students in the course should be able to read, understand, and critique current, scholarly literature on the topic of Neuroscience, Memory, and Learning. When this course is cross-listed and concurrent with CBEN411, students that enroll in CBEN511 will complete additional and/or more complex assignments. Pre-requisites: CBEN110, CBEN120, CHGN221, CHGN222, PHGN100, and PHGN200. 3 hours lecture, 3 semester hours.

CBEN513. SELECTED TOPICS IN CHEMICAL ENGINEERING. 1-3 Semester Hr.
Equivalent with CHEN513,
Selected topics chosen from special interests of instructor and students. Course may be repeated for credit on different topics. Prerequisite: none. 1 to 3 semester hours lecture/discussion; 1 to 3 semester hours.

CBEN516. TRANSPORT PHENOMENA. 3.0 Semester Hrs.
Equivalent with CHEN516,
(I) Principles of momentum, heat, and mass transport with applications to chemical and biological processes. Analytical methods for solving ordinary and partial differential equations in chemical engineering with an emphasis on scaling and approximation techniques. Convective transport in the context of boundary layer theory and development of heat and mass transfer coefficients. Introduction to computational methods for solving coupled transport problems in irregular geometries. 3 hours lecture; 3 semester hours.

CBEN518. REACTION KINETICS AND CATALYSIS. 3.0 Semester Hrs.
Equivalent with CHEN518,
(I) This course applies the fundamentals of kinetics, transport and thermodynamics to the analysis of gas-phase and catalytic reactions. A focus is placed on a molecular description of chemical kinetics with applications to the design and analysis chemical and biological reactors, complex reaction networks, and catalysis. Prerequisite: CBEN418 or equivalent. 3 hours lecture; 3 semester hours.

CBEN524. COMPUTER-AIDED PROCESS SIMULATION. 3.0 Semester Hrs.
Equivalent with CHEN524,
Advanced concepts in computer-aided process simulation are covered. Topics include optimization, heat exchanger networks, data regression analysis, and separations systems. Use of industry-standard process simulation software (Aspen Plus) is stressed. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN531. IMMUNOLOGY FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
Equivalent with BELS531,
(II) This course introduces the basic concepts of immunology and their applications in engineering and science. We will discuss the molecular, biochemical and cellular aspects of the immune system including structure and function of the innate and acquired immune systems. Building on this, we will discuss the immune response to infectious agents and the material science of introduced implants and materials such as heart valves, artificial joints, organ transplants and lenses. We will also discuss the role of the immune system in cancer, allergies, immune deficiencies, vaccination and other applications such as immunoassay and flow cytometry. Prerequisites: Biology BIOL110 or equivalent or graduate standing.

CBEN535. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with CHEN435,CHEN535,MLGN535,PHGN435,PHGN535,
Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. 1 hour lecture, 4 hours lab; 3 semester hours.

CBEN550. MEMBRANE SEPARATION TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN550,
This course is an introduction to the fabrication, characterization, and application of synthetic membranes for gas and liquid separations. Industrial membrane processes such as reverse osmosis, filtration, pervaporation, and gas separations will be covered as well as new applications from the research literature. The course will include lecture, experimental, and computational (molecular simulation) laboratory components. Prerequisites: CBEN375, CBEN430. 3 hours lecture; 3 semester hours.

CBEN554. APPLIED BIOINFORMATICS. 3.0 Semester Hrs.
Equivalent with BELS554,
(II) In this course we will discuss the concepts and tools of bioinformatics. The molecular biology of genomics and proteomics will be presented and the techniques for collecting, storing, retrieving and processing such data will be discussed. Topics include analyzing DNA, RNA and protein sequences, gene recognition, gene expression, protein structure prediction, modeling evolution, utilizing BLAST and other online tools for the exploration of genome, proteome and other available databases. In parallel, there will be an introduction to the PERL programming language. Practical applications to biological research and disease will be presented and students given opportunities to use the tools discussed. General Biology BIOL110 or Graduate standing.

CBEN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.
Equivalent with BELS555,CHEN555,CHGN555,MLGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN568. INTRODUCTION TO CHEMICAL ENGINEERING RESEARCH AND TEACHING. 3.0 Semester Hrs.
Equivalent with CHEN568,
(I) Students will be expected to apply chemical engineering principles to critically analyze theoretical and experimental research results in the chemical engineering literature, placing it in the context of the related literature, and interact effectively with students in classroom. Skills to be developed and discussed include oral presentations, technical writing, proposal writing, principles of hypothesis driven research, critical review of the literature, research ethics, research documentation (the laboratory notebook), research funding, types of research, pedagogical methods, and assessment tools. Prerequisites: graduate student in Chemical and Biological Engineering in good standing. 3 semester hours.

CBEN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN569,EGGN569,MEGN569,MLGN569,MTGN569,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

CBEN570. INTRODUCTION TO MICROFLUIDICS. 3.0 Semester Hrs.
Equivalent with CHEN570,
This course introduces the basic principles and applications of microfluidics systems. Concepts related to microscale fluid mechanics, transport, physics, and biology are presented. To gain familiarity with small-scale systems, students are provided with the opportunity to design, fabricate, and test a simple microfluidic device. Students will critically analyze the literature in this emerging field. Prerequisites: CBEN307 or equivalent. 3 hours lecture, 3 semester hours.

CBEN580. NATURAL GAS HYDRATES. 3.0 Semester Hrs.
Equivalent with CHEN580,
The purpose of this class is to learn about clathrate hydrates, using two of the instructor's books, (1) Clathrate Hydrates of Natural Gases, Third Edition (2008) co authored by C.A.Koh, and (2) Hydrate Engineering, (2000). Using a basis of these books, and accompanying programs, we have abundant resources to act as professionals who are always learning. 3 hours lecture; 3 semester hours.

CBEN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.
Equivalent with CHEN584,
The basic principles involved in the preparation, charac terization, testing and theory of heterogeneous and homo geneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN604. TOPICAL RESEARCH SEMINARS. 1.0 Semester Hr.
Equivalent with CHEN604,
Lectures, reports, and discussions on current research in chemical engineering, usually related to the student?s thesis topic. Sections are operated independently and are directed toward different research topics. Course may be repeated for credit. Prerequisite: none. 1 hour lecture-discussion; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CBEN605. COLLOQUIUM. 1.0 Semester Hr.
Equivalent with CHEN605,
Students will attend a series of lectures by speakers from industry, academia, and government. Primary emphasis will be on current research in chemical engineering and related disciplines, with secondary emphasis on ethical, philosophical, and career-related issues of importance to the chemical engineering profession. Prerequisite: Graduate status. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 10 hours.

CBEN608. ADVANCED TOPICS IN FLUID MECHANICS. 1-3 Semester Hr.
Equivalent with CHEN608,
Indepth analysis of selected topics in fluid mechanics with special emphasis on chemical engineering applications. Prerequisite: CBEN508. 1 to 3 hours lecture discussion; 1 to 3 semester hours.

CBEN609. ADVANCED TOPICS IN THERMODYNAMICS. 1-3 Semester Hr.
Equivalent with CHEN609,
Advanced study of thermodynamic theory and application of thermodynamic principles. Possible topics include stability, critical phenomena, chemical thermodynamics, thermodynamics of polymer solutions and thermodynamics of aqueous and ionic solutions. Prerequisite: none. 1 to 3 semester hours.

CBEN610. APPLIED STATISTICAL THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with CHEN610,
Principles of relating behavior to microscopic properties. Topics include element of probability, ensemble theory, application to gases and solids, distribution theories of fluids, and transport properties. Prerequisite: none. 3 hours lecture; 3 semester hours.

CBEN617. GRADUATE TRANSPORT PHENOMENA II. 3.0 Semester Hrs.
(II) Analysis of momentum, heat, and mass transfer problems using advanced analytical and numerical methods with an emphasis on coupled transport problems and irregular geometries. Advanced analytical techniques may include regular and singular perturbation analysis, eigenvalue problems, finite Fourier transforms, and Laplace transforms. Numerical methods for solving differential equations include finite differences, finite elements, Monte Carlo methods, and computational fluid dynamics. Prerequisite: CBEN516. 3 hours lecture; 3 semester hours.

CBEN620. ENGINEERING OF SOFT MATTER. 3.0 Semester Hrs.
(II) Soft matter is a field of inquiry involving physical systems having low moduli and which are structured on length scales ranging from about 10 nanometers up to 100 microns. This graduate level class provides a survey of relevant material systems including polymers, colloids, surfactants, liquid crystals, and biological materials. The course emphasis is on the chemical physics of soft materials and therefore requires a high level of mathematical sophistication; students should have the equivalent of one semester of graduate level applied mathematics as a prerequisite. A term paper in the form of a short publishable review of a relevant topic is a major component of the class. Prerequisites: the equivalent of one semester of graduate level applied mathematics. 3 hours lecture; 3 semester hours.

CBEN624. APPLIED STATISTICAL MECHANICS. 4.0 Semester Hrs.
(II) This course will introduce the both rigorous and approximate theories to estimate the macroscopic thermodynamic properties of systems based on laws that control the behavior of molecules. Course contents include classical dynamics and phase space, different types of ensembles, ideal and interacting gases, modern theory of liquids, ideal solids, as well as molecular simulation techniques. Prerequisite: undergraduate-level classical thermodynamics. 4 hours lecture; 4 semester hours.

CBEN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.
Equivalent with CHEN625,
Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: CBEN509 or equivalent, CBEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CBEN690. SUPERVISED TEACHING OF CHEMICAL ENGINEERING. 2.0 Semester Hrs.
Equivalent with CHEN690,
Individual participation in teaching activities. Discussion, problem review and development, guidance of laboratory experiments, course development, supervised practice teaching. Course may be repeated for credit. Prerequisite: Graduate standing, appointment as a graduate student instructor. 6 to 10 hours supervised teaching; 2 semester hours.

CBEN698. SPECIAL TOPICS IN CHEMICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CBEN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CBEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with CHEN707,

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

CHEMISTRY (CHGN)

CHGN111. INTRODUCTORY CHEMISTRY. 3.0 Semester Hrs.
(S) Introductory college chemistry. Elementary atomic structure and the periodic chart, chemical bonding, chemical reactions and stoichiometry of chemical reactions, chemical equilibrium, thermochemistry, and properties of gases. Must not be used for elective credit. Does not apply toward undergraduate degree or g.p.a. 3 hours lecture and 3 hours lab; 3 semester hours.

CHGN121. PRINCIPLES OF CHEMISTRY I. 4.0 Semester Hrs.
(I, II) Study of matter and energy based on atomic structure, correlation of properties of elements with position in periodic chart, chemical bonding, geometry of molecules, phase changes, stoichiometry, solution chemistry, gas laws, and thermochemistry. 3 hours lecture, 3 hours lab; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

CHGN122. PRINCIPLES OF CHEMISTRY II (SC1). 4.0 Semester Hrs.
(I, II, S) Continuation of CHGN121 concentrating on chemical kinetics, gas laws, thermodynamics, electrochemistry and chemical equilibrium (acid- base, solubility, complexation, and redox). Laboratory experiments emphasizing quantitative chemical measurements. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab, 4 semester hours.

CHGN125. MOLECULAR ENGINEERING & MATERIALS CHEMISTRY. 4.0 Semester Hrs.
(I,II) Studies of the interactions of matter and energy in chemical reactions and physical processes. Building on principles from CHGN121, the course systematically explores the relationships between processes, structures and properties, starting from the atomic and molecular level. It provides a framework to apply knowledge of chemical bonding and material properties to engineering design, with an emphasis on the Engineering Grand Challenges and the discovery of new process-structure-property relationships. There is a strong focus on the underlying principles of kinetics and equilibrium, and their general applicability, strongly rooted in the first and second law of thermodynamics. Examples of these principles come primarily from solid-state systems. Laboratory experiments emphasize conceptual understanding of structure-property relationships through both hands-on and computational analysis, reinforced by quantitative chemical measurements. Prerequisite: Grade of C- or better in CHGN121. 3 hours lecture; 3 hours lab; 4 semester hours.

CHGN198. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN209. INTRODUCTION TO CHEMICAL THERMODYNAMICS. 3.0 Semester Hrs.
Equivalent with DCGN209,
(I, II, S) Introduction to the fundamental principles of classical thermodynamics, with particular emphasis on chemical and phase equilibria. Volume-temperature-pressure relationships for solids, liquids, and gases; ideal and non-ideal gases. Introduction to kineticmolecular theory of ideal gases and the Maxwell-Boltzmann distributions. Work, heat, and application of the First Law to closed systems, including chemical reactions. Entropy and the Second and Third Laws; Gibbs Free Energy. Chemical equilibrium and the equilibrium constant; introduction to activities & fugacities. One- and two-component phase diagrams; Gibbs Phase Rule. May not also receive credit for CBEN210 or GEGN330. Prerequisites: CHGN121, CHGN122 or CHGN125, MATH111, MATH112, PHGN100. 3 hours lecture; 3 semester hours.

CHGN221. ORGANIC CHEMISTRY I. 3.0 Semester Hrs.
(I,S) Structure, properties, and reactions of the important classes of organic compounds, introduction to reaction mechanisms. Prerequisites: Grade of C- or better in CHGN122 or CHGN125. 3 hours lecture; 3 semester hours.

CHGN222. ORGANIC CHEMISTRY II. 3.0 Semester Hrs.
(II, S) Continuation of CHGN221. Prerequisites: Grade of C- or better in CHGN221. 3 hours lecture; 3 semester hours.

CHGN223. ORGANIC CHEMISTRY I LABORATORY. 1.0 Semester Hr.
(I,II, S) Laboratory exercises including purification techniques, synthesis, and characterization. Experiments are designed to support concepts presented in the CHGN221. Students are introduced to Green Chemistry principles and methods of synthesis and the use of computational software. Prerequisites: CHGN221 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN224. ORGANIC CHEMISTRY II LABORATORY. 1.0 Semester Hr.
(II, S) Laboratory exercises using more advanced synthesis techniques. Experiments are designed to support concepts presented in CHGN222. Prerequisites: CHGN221, CHGN223, and CHGN222 or concurrent enrollment. 3 hours laboratory, 1 semester hour.

CHGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN311. INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY. 3.0 Semester Hrs.
(II) The primary objective of this course is to provide all students a suitable background to understand the role nanotechnology will play in future technologies and the underpinning principals involved. Prerequisites: CHGN121 and CHGN122 or CHGN125. 3 hours lecture; 3 semester hours.

CHGN323. QUALITATIVE ORGANIC ANALYSIS AND APPLIED SPECTROSCOPY. 2.0 Semester Hrs.
(II) Identification, separation and purification of organic compounds including use of modern physical and instrumental methods. Prerequisite: Grade of C- or better in CHGN222, CHGN224. 1 hour lecture; 3 hours lab; 2 semester hours.

CHGN335. INSTRUMENTAL ANALYSIS. 3.0 Semester Hrs.
(II) Principles of AAS, AES, Visible-UV, IR, NMR, XRF, XRD, XPS, electron, and mass spectroscopy; gas and liquid chromatography; data interpretation. Prerequisite: Grade of C- or better in CHGN122. 3 hours lecture; 3 semester hours.

CHGN336. ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.
(I) Theory and techniques of gravimetry, titrimetry (acid-base, complexometric, redox, precipitation), electrochemical analysis, chemical separations; statistical evaluation of data. Prerequisite: Grade of C- or better in both CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN337. ANALYTICAL CHEMISTRY LABORATORY. 1.0 Semester Hr.
(I) (WI) Laboratory exercises emphasizing sample preparation and instrumental methods of analysis. Prerequisite: CHGN336 or concurrent enrollment. 3 hours lab; 1 semester hour.

CHGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) Supervised, full-time, chemistry-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

CHGN341. INORGANIC CHEMISTRY I. 3.0 Semester Hrs.
(I) The chemistry of the elements and periodic trends in reactivity is discussed. Particular concepts covered include group theory, symmetry, bonding in ionic and metallic crystal, acid-base theories, coordination chemistry, ligand field theory and radioactivity. Prerequisite: CHGN222 and CHGN209. 3 hours lecture; 3 semester hours.

CHGN351. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE I. 4.0 Semester Hrs.
(I,II,S) A study of chemical systems from a molecular physical chemistry perspective. Includes an introduction to quantum mechanics, atoms and molecules, spectroscopy, bonding and symmetry, and an introduction to modern computational chemistry. Prerequisite: MATH225; PHGN200; Grade of C- or better in CHGN 122 or CHGN 125; and Grade of C- or better in CHGN209 or CBEN210. 3 hours lecture; 3 hours lab; 4 semester hours.

CHGN353. PHYSICAL CHEMISTRY: A MOLECULAR PERSPECTIVE II. 4.0 Semester Hrs.
(II) A continuation of CHGN351. Includes statistical thermodynamics, chemical kinetics, chemical reaction mechanisms, electrochemistry, and selected additional topics. Prerequisite: CHGN351. 3 hours lecture; 3 hours laboratory; 4 semester hours.

CHGN395. INTRODUCTION TO UNDERGRADUATE RESEARCH. 1.0 Semester Hr.
(I) (WI) Introduction to Undergraduate Research is designed to introduce students to the research endeavor. Topics include ethics, hypothesis testing, critical evaluation of the scientific literature, scientific writing, bibliographic software, and proposal preparation. Prerequisites: Completion of the chemistry curriculum through the Spring semester of the sophomore year. Credit: 1 semester hour.

CHGN396. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.
(I,II,S) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Prerequisites: None. Variable credit; 1 to 5 credit hours. Repeatable for credit. Seniors should take CHGN495 instead of CHGN396.

CHGN398. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN401. INORGANIC CHEMISTRY II. 3.0 Semester Hrs.
(II) The chemistry of the elements and several applications are related to inorganic chemistry are considered in this course. Particular concepts covered include experimental techniques, chemistry specific to groups of elements, catalysis and industrial processes, inorganic materials and nanotechnology, and other applications of inorganic chemistry. Prerequisite: CHGN341. 3 hours lecture; 3 semester hours.

CHGN403. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGC505,
(II) Processes by which natural and anthro?pogenic chemicals interact, react and are transformed and redistributed in various environmental compartments. Air, soil and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized envi? ronments such as waste treatment facilities and the upper atmosphere. Prerequisites: CHGN222, CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGN406. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
(II) A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisites: CHGN121, CHGN122, and GEGN101. 4 hours lecture; 4 semester hours.

CHGN410. SURFACE CHEMISTRY. 3.0 Semester Hrs.
Equivalent with MLGN510,
(II) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and micro - emulsions, the solid/gas interface, surface analytical techniques, van der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: CHGN209. 3 hours lecture; 3 semester hours.

CHGN411. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.
(II) This course is designed for those who have a budding interest radiochemistry and its applications. A brief overview of radioactivity and general chemistry will be provided in the first three weeks of the course. Follow-on weeks will feature segments focusing on the radiochemistry in the nuclear fuel cycle, radioisotope production, nuclear forensics and the environment. Prerequisite: CHGN121 and CHGN122. 3 hours lecture, 3 semester hours.

CHGN422. POLYMER CHEMISTRY LABORATORY. 1.0 Semester Hr.
(I) Prerequisites: CHGN221, CHGN223. 3 hours lab; 1 semester hour.

CHGN428. BIOCHEMISTRY. 3.0 Semester Hrs.
(I) Introductory study of the major molecules of biochemistry: amino acids, proteins, enzymes, nucleic acids, lipids, and saccharides- their structure, chemistry, biological function, and biosynthesis. Stresses bioenergetics and the cell as a biological unit of organization. Discussion of classical genetics, molecular genetics, and protein synthesis. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN429. BIOCHEMISTRY II. 3.0 Semester Hrs.
(I) A continuation of CHGN428. Topics include: nucleotide synthesis; DNA repair, replication and recombination; transcription, translation and regulation; proteomics; lipid and amino acid synthesis; protein target and degradation; membranes; receptors and signal transduction. Prerequisites: CHGN428. 3 hours lecture; 3 semester hours.

CHGN430. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.
Equivalent with CHEN415,MLGN530,
(I) An introduction to the chemistry and physics of macromolecules. Topics include the properties and statistics of polymer solutions, measurements of molecular weights, molecular weight distributions, properties of bulk polymers, mechanisms of polymer formation, and properties of thermosets and thermoplastics including elastomers. Pre requisite: CHGN222. 3 hour lecture, 3 semester hours.

CHGN462. MICROBIOLOGY. 3.0 Semester Hrs.
Equivalent with CHGN562,ESGN580,
(II) This course will cover the basic fundamentals of microbiology, such as structure and function of prokaryotic versus eukaryotic cells; viruses; classification of microorganisms; microbial metabolism, energetics, genetics, growth and diversity, microbial interactions with plants, animals, and other microbes. Special focus will be on pathogenic bacteriology, virology, and parasitology including disease symptoms, transmission, and treatment. Prerequisite: none. 3 hours lecture, 3 semester hours.

CHGN475. COMPUTATIONAL CHEMISTRY. 3.0 Semester Hrs.
(II) This class provides a survey of techniques of computational chemistry, including quantum mechanics (both Hartree-Fock and density functional approaches) and molecular dynamics. Emphasis is given to the integration of these techniques with experimental programs of molecular design and development. Prerequisites: CHGN351, CHGN401. 3 hours lecture; 3 semester hours.

CHGN490. CHEMISTRY FIELD SESSION. 6.0 Semester Hrs.
(S) (WI) Professional-level chemistry experience featuring modules including organic/polymer synthesis and characterization, inorganic nanomaterial investigations, computational chemistry, environmental chemical analysis , biochemistry and technical report writing. Prerequisites: CHGN323, CHGN341, and CHGN353. 6-week summer session; 6 semester hours.

CHGN495. UNDERGRADUATE RESEARCH. 1-5 Semester Hr.
(I, II, S) (WI) Individual research project under direction of a member of the Departmental faculty. Prerequisites: selection of a research topic and advisor, preparation and approval of a research proposal, completion of chemistry curriculum through the junior year. Variable credit; 1 to 5 credit hours. Repeatable for credit.

CHGN497. INTERNSHIP. 1-6 Semester Hr.
(I, II, S) Individual internship experience with an industrial, academic, or governmental host supervised by a Departmental faculty member. Prerequisites: Completion of chemistry curriculum through the junior year. Variable credit; 1 to 6 credit hours.

CHGN498. SPECIAL TOPICS IN CHEMISTRY. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CHGN499. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CHGN502. ADVANCED INORGANIC CHEMISTRY. 3.0 Semester Hrs.
(II) Detailed examination of topics such as ligand field theory, reaction mechanisms, chemical bonding, and structure of inorganic compounds. Emphasis is placed on the correlations of the chemical reactions of the elements with periodic trends and reactivities. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN503. ADV PHYSICAL CHEMISTRY I. 4.0 Semester Hrs.
(II) Quantum chemistry of classical systems. Principles of chemical thermodynamics. Statistical mechanics with statistical calculation of thermodynamic properties. Theories of chemical kinetics. Prerequisite: none. 4 hours lecture; 4 semester hours.

CHGN505. ADVANCED ORGANIC CHEMISTRY. 3.0 Semester Hrs.
Detailed discussion of the more important mechanisms of organic reaction. Structural effects and reactivity. The application of reaction mechanisms to synthesis and structure proof. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN507. ADVANCED ANALYTICAL CHEMISTRY. 3.0 Semester Hrs.
(I) Review of fundamentals of analytical chemistry. Literature of analytical chemistry and statistical treatment of data. Manipulation of real substances; sampling, storage, decomposition or dissolution, and analysis. Detailed treatment of chemical equilibrium as related to precipitation, acid-base, complexation and redox titrations. Potentiometry and UV-visible absorption spectrophotometry. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN508. ANALYTICAL SPECTROSCOPY. 3.0 Semester Hrs.
(II) Detailed study of classical and modern spectroscopic methods; emphasis on instrumentation and application to analytical chemistry problems. Topics include: UV-visible spectroscopy, infrared spectroscopy, fluorescence and phosphorescence, Raman spectroscopy, arc and spark emission spectroscopy, flame methods, nephelometry and turbidimetry, reflectance methods, Fourier transform methods in spectroscopy, photoacoustic spectroscopy, rapid-scanning spectroscopy. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN510. CHEMICAL SEPARATIONS. 3.0 Semester Hrs.
(II) Survey of separation methods, thermodynamics of phase equilibria, thermodynamics of liquid-liquid partitioning, various types of chromatography, ion exchange, electrophoresis, zone refining, use of inclusion compounds for separation, application of separation technology for determining physical constants, e.g., stability constants of complexes. Prerequisite: CHGN507. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN511. APPLIED RADIOCHEMISTRY. 3.0 Semester Hrs.
(II) The Applied Radiochemistry course is designed for those who have a budding interest radiochemistry and its applications. A brief overview of radioactivity and general chemistry will be provided in the first three weeks of the course. Follow-on weeks will feature segments focusing on the radiochemistry in the nuclear fuel cycle, radioisotope production, nuclear forensics and the environment. Prerequisites: CHGN121/ CHGN122. 3 hours lecture and discussion; 3 semester hours.

CHGN515. CHEMICAL BONDING IN MATERIALS. 3.0 Semester Hrs.
(I) Introduction to chemical bonding theories and calculations and their applications to solids of interest to materials science. The relationship between a material?s properties and the bonding of its atoms will be examined for a variety of materials. Includes an introduction to organic polymers. Computer programs will be used for calculating bonding parameters. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGN523. SOLID STATE CHEMISTRY. 3.0 Semester Hrs.
(I) Dependence of properties of solids on chemical bonding and structure; principles of crystal growth, crystal imperfections, reactions and diffusion in solids, and the theory of conductors and semiconductors. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN536. ADVANCED POLYMER SYNTHESIS. 3.0 Semester Hrs.
(II) An advanced course in the synthesis of macromolecules. Various methods of polymerization will be discussed with an emphasis on the specifics concerning the syntheses of different classes of organic and inorganic polymers. Prerequisite: CHGN430, ChEN415, MLGN530. 3 hours lecture, 3 semester hours.

CHGN538. ORGANIC SEMICONDUCTORS: NEW TECHNOLOGIES FOR EMERGING APPLICATIONS. 3.0 Semester Hrs.
(II) Organic Light Emitting Diodes (OLEDs) is a display technology that can be found in many commercial products such as the smartphones and tablets. This technology was on the R&D bench-top just 10 years ago and has now reached high volume manufacturing. Other related technologies like organic photovoltaics (OPV) and organic thin film transistors (OTFT) are now on the heels of commercialization as well. This course will provide an overview on how this meteoric rise from bench-top to commercial products occurred as well as the design, synthesis and uses of conjugated organic small molecules, oligomers and polymers in applications such as OLEDs (for flat panel displays and lighting), OPV, OTFT, and sensors. Additional topics to be covered are factors governing the materials physical properties and structure-property relationship in electronic device applications. The prospect of using low cost printing techniques such as inkjet, screen, and gravure printing in the fabrication of roll-to-roll organic based devices will be discussed. Encapsulation, lifetime and reliability issues will also be presented. Prerequisites: Organic Chemistry 1 & 2 are encouraged. 3 hours lecture; 3 semester hours.

CHGN540. PROFESSION SKILLS FOR CHEMICAL SCIENTISTS. 1.0 Semester Hr.
(I) The goal of this course is to provide students a set of skills that are complementary to their core education. The contents of this course cover a broad range of topics that will provide the participants a perspective on careers in science and the skill sets necessary to be successful in each. These skills are in line with the latest recommendations of the American Chemical Society (ACS) and CSM educational goals. In particular, the 2013 ACS Presidential Commission Report on Graduate Education in the Chemical Sciences presents a platform for educational reform that includes a focus on multi-level (from general public to specialists) and multi-platform communication (formal and informal, written, oral), an understanding of the global chemical enterprise and the career possibilities within each, an understanding of networking and collaboration, etc. 1 hour lecture; 1 semester hour.

CHGN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.
Equivalent with BELS555,CBEN555,CHEN555,MLGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

CHGN560. GRADUATE SEMINAR, M.S.. 1.0 Semester Hr.
(I, II) Required for all candidates for the M.S. and Ph.D. degrees in chemistry and geochemistry. M.S. students must register for the course during each semester of residency. Ph.D. students must register each semester until a grade is received satisfying the prerequisites for CHGN660. Presentation of a graded non-thesis seminar and attendance at all departmental seminars are required. Prerequisite: Graduate student status. 1 semester hour.

CHGN580. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
(II) Application of X-ray diffraction techniques for crystal and molecular structure determination of minerals, inorganic and organometallic compounds. Topics include the heavy atom method, data collection by moving film techniques and by diffractometers, Fourier methods, interpretation of Patterson maps, refinement methods, direct methods. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN581. ELECTROCHEMISTRY. 3.0 Semester Hrs.
(I) Introduction to theory and practice of electrochemistry. Electrode potentials, reversible and irreversible cells, activity concept. Interionic attraction theory, proton transfer theory of acids and bases, mechanisms and fates of electrode reactions. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN583. PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES. 3.0 Semester Hrs.
(II) Instru mental techniques for the characterization of surfaces of solid materials; Applications of such techniques to polymers, corrosion, metallurgy, adhesion science, microelectronics. Methods of analysis discussed: x-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), ion scattering spectroscopy (ISS), secondary ion mass spectrometry (SIMS), Rutherford backscattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive x-ray analysis; principles of these methods, quantification, instrumentation, sample preparation. Prerequisite: B.S. in Metallurgy, Chemistry, Chemical Engineering, Physics. 3 hours lecture; 3 semester hours.

CHGN584. FUNDAMENTALS OF CATALYSIS. 3.0 Semester Hrs.
(II) The basic principles involved in the preparation, characterization, testing and theory of heterogeneous and homo geneous catalysts are discussed. Topics include chemisorption, adsorption isotherms, diffusion, surface kinetics, promoters, poisons, catalyst theory and design, acid base catalysis and soluble transition metal complexes. Examples of important industrial applications are given. Prerequisite: CHGN222. 3 hours lecture; 3 semester hours.

CHGN585. CHEMICAL KINETICS. 3.0 Semester Hrs.
(II) Study of kinetic phenomena in chemical systems. Attention devoted to various theoretical approaches. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGN598. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN625. MOLECULAR SIMULATION. 3.0 Semester Hrs.
Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by indepth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: ChEN509 or equivalent, ChEN610 or equivalent recommended. 3 hours lecture; 3 semester hours.

CHGN660. GRADUATE SEMINAR, Ph.D.. 1.0 Semester Hr.
(I, II) Required of all candidates for the doctoral degree in chemistry or geochemistry. Students must register for this course each semester after completing CHGN560. Presentation of a graded nonthesis seminar and attendance at all department seminars are required. Prerequisite: CHGN560 or equivalent. 1 semester hour.

CHGN698. SPECIAL TOPICS IN CHEMISTRY. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

CHEMISTRY, GEOCHEMISTRY (CHGC)

CHGC503. INTRODUCTION TO GEOCHEMISTRY. 3.0 Semester Hrs.
(I) A comprehensive introduction to the basic concepts and principles of geochemistry, coupled with a thorough overview of the related principles of thermodynamics. Topics covered include: nucleosynthesis, origin of earth and solar system, chemical bonding, mineral chemistry, elemental distributions and geochemical cycles, chemical equilibrium and kinetics, isotope systematics, and organic and biogeochemistry. Prerequisite: Introductory chemistry, mineralogy and petrology. 3 hours lecture; 3 semester hours.

CHGC504. METHODS IN GEOCHEMISTRY. 2.0 Semester Hrs.
Sampling of natural earth materials including rocks, soils, sediments, and waters. Preparation of naturally heterogeneous materials, digestions, and partial chemical extractions. Principles of instrumental analysis including atomic spectroscopy, mass separations, and chromatography. Quality assurance and quality control. Interpretation and assessment of geochemical data using statistical methods. Prerequisite: Graduate standing in geochemistry or environmental science and engineering. 2 hours lecture; 2 semester hours.

CHGC505. INTRODUCTION TO ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGN403,
(II) Processes by which natural and anthropogenic chemicals interact, react, and are transformed and redistributed in various environmental compartments. Air, soil, and aqueous (fresh and saline surface and groundwaters) environments are covered, along with specialized environments such as waste treatment facilities and the upper atmosphere. Meets with CHGN403. CHGN403 and CHGC505 may not both be taken for credit. Prerequisites: GEGN101, CHGN122 and CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

CHGC506. WATER ANALYSIS LABORATORY. 2.0 Semester Hrs.
Instrumental analysis of water samples using spectroscopy and chromatography. Methods for field collection of water samples and field measurements. The development of laboratory skills for the use of ICP-AES, HPLC, ion chromatography, and GC. Laboratory techniques focus on standard methods for the measurement of inorganic and organic constituents in water samples. Methods of data analysis are also presented. Prerequisite: Introductory chemistry, graduate standing. 3 hour laboratory, 1 hour lecture, 2 semester hours.

CHGC509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.
Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

CHGC511. GEOCHEMISTRY OF IGNEOUS ROCKS. 3.0 Semester Hrs.
A survey of the geochemical characteristics of the various types of igneous rock suites. Application of major element, trace element, and isotope geochemistry to problems of their origin and modification. Prerequisite: Undergraduate mineralogy and petrology. 3 hours lecture; 3 semester hours. Offered alternate years.

CHGC514. GEOCHEMISTRY THERMODYNAMICS AND KINETICS. 3.0 Semester Hrs.
(II) Fundamental principles of classical thermodynamics and kinetics with specific application to the earth sciences. Volume-temperature ? pressure relationships for solids, liquids, gases and solutions. Energy and the First Law, Entropy and the Second and Third Laws. Gibbs Free Energy, chemical equilibria and the equilibrium constant. Solutions and activity-composition relationships for solids, fluids and gases. Phase equilibria and the graphical representation of equilibira. Application of the fundamentals of kinetics to geochemical examples. Prerequisite: Introductory chemistry, introductory thermodynamics, mineralogy and petrology. 3 hours lecture, 3 semester hours. Offered in alternate years.

CHGC527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.
A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

CHGC555. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CHGC562. MICROBIOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
This course will cover the basic fundamentals of microbiology, such as structure and function of procaryotic versus eucaryotic cells; viruses; classification of micro-organisms; microbial metabolism, energetics, genetics, growth and diversity; microbial interactions with plants, animals, and other microbes. Additional topics covered will include various aspects of environmental microbiology such as global biogeochemical cycles, bioleaching, bioremediation, and wastewater treatment. Prerequisite: ESGN301. 3 hours lecture, 3 semester hours. Offered alternate years.

CHGC563. ENVIRONMENTAL MICROBIOLOGY. 2.0 Semester Hrs.
An introduction to the microorganisms of major geochemical importance, as well as those of primary importance in water pollution and waste treatment. Microbes and sedimentation, microbial leaching of metals from ores, acid mine water pollution, and the microbial ecology of marine and freshwater habitats are covered. Prerequisite: none. 1 hour lecture, 3 hours lab; 2 semester hours. Offered alternate years.

CHGC564. BIOGEOCHEMISTRY AND GEOMICROBIOLOGY. 3.0 Semester Hrs.
Designed to give the student an understanding of the role of living things, particularly microorganisms, in the shaping of the earth. Among the subjects will be the aspects of living processes, chemical composition and characteristics of biological material, origin of life, role of microorganisms in weathering of rocks and the early diagenesis of sediments, and the origin of petroleum, oil shale, and coal. Prerequisite: none. 3 hours lecture; 3 semester hours.

CHGC598. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CHGC698. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CHGC699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CIVIL AND ENVIRONMENTAL ENGINEERING (CEEN)

CEEN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN210. INTRODUCTION TO CIVIL INFRASTRUCTURE. 1.5 Semester Hr.
(I) An introduction to civil infrastructure systems, including the analysis, design and management of infrastructure that supports human activity, including transportation (road, rail, aviation), water and wastewater, communications and power. 0.75 hours lecture; 2.25 hours lab; 1.5 semester hours.

CEEN241. STATICS. 3.0 Semester Hrs.
Equivalent with DCGN241,
(I, II, S) Forces, moments, couples, equilibrium, centroids and second moments of areas, volumes and masses, hydrostatics, friction, virtual work. Applications of vector algebra to structures. Prerequisite: PHGN100 and credit or concurrent enrollment in MATH112. 3 hours lecture; 3 semester hours.

CEEN267. EPICS II: CIVIL ENGINEERING. 3.0 Semester Hrs.
Equivalent with EPIC267,
(II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently.Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 3 hours lecture; 3 semester hours.

CEEN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN301. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING I. 3.0 Semester Hrs.
Equivalent with EGGN353,ESGN353,
(I, II) This course introduces fundamentals of environmental science & engineering as applied to water resource management and environmental problem solving. Topics include environmental regulation, toxicology, material balance, applications in environmental chemistry, hydrology, water quality management, water supply and treatment, and wastewater treatment and reuse. Topical discussions will address major sources and concerns in measurement, practice and underlying theory in the field of environmental engineering. The course also includes field trips to local water and wastewater treatment facilities to integrate theory with practice. Prerequisites: CHGN122, PHGN100. 3 hours lecture; 3 semester hours.

CEEN302. FUNDAMENTALS OF ENVIRONMENTAL SCIENCE AND ENGINEERING II. 3.0 Semester Hrs.
Equivalent with EGGN354,ESGN354,
(I, II) Introductory level fundamentals in atmospheric systems, air pollution control, solid waste management, hazardous waste management, waste minimization, pollution prevention, role and responsibilities of public institutions and private organizations in environmental management(relative to air, solid and hazardous waste). Prerequisite: CHGN122, PHGN100 and MATH213. 3 hours lecture; 3 semester hours.

CEEN303. ENVIRONMENTAL ENGINEERING LABORATORY. 3.0 Semester Hrs.
Equivalent with ESGN355,
(I) This course introduces the laboratory and experimental techniques used for generating and interpreting data in environmental science and engineering related to water, land, and environmental health. An emphasis is placed on quantitative chemical and microbiological analysis of water and soil samples relevant to water supply and wastewater discharge. Topics include basic water quality measurements (pH, conductivity, etc.) and quantitative analysis of chemicals by chromatographic and mass spectrometric techniques. Advanced topics include quantitative and qualitative analysis of bioreactor performance, bench testing for water treatment, and measurement and control of disinfection by-products. Prerequisites: CEEN301 or CEEN302. 1 hour lecture, 6 hours lab; 3 semester hours.

CEEN310. FLUID MECHANICS FOR CIVIL AND ENVIRONMENTAL ENGINEERING. 3.0 Semester Hrs.
(I, II) The study and application of principles of incompressible fluid mechanics. Topics include: hydrostatic forces on submerged surfaces, buoyancy, control volume analysis, conservation of mass, fluid motion, Bernoulli's equation and conservation of energy, momentum, dimensional analysis, internal flow (pipe systems), external flow (drag and lift), flow in open channels, and hydraulic jumps. The course will also introduce concepts about municipal water supply networks and storm water drainage and wastewater collection and treatment systems. May not also receive credit for PEGN251 or MEGN351. Prerequisites: PHGN100. Co-requisites: CEEN241. 3 lecture hours, 3 semester hours.

CEEN311. MECHANICS OF MATERIALS. 3.0 Semester Hrs.
Equivalent with EGGN320,
(I, II, S) Fundamentals of stresses and strains, material properties including axial, torsional, bending, and combined loadings. Stress at a point; stress transformations and Mohr's circle for stress; beam deflections, thin-wall pressure vessels, columns and buckling, and stress concentrations. May not also receive credit for MEGN312. Prerequisite: CEEN241. 3 hours lecture; 3 semester hours.

CEEN312. SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN361,
(I, II) An introductory course covering the engineering properties of soil, soil phase relationships and classification. Principle of effective stress. Seepage through soils and flow nets. Soil compressibility, consolidation and settlement prediction. Shear strength of soils. Prerequisite: CEEN311. 3 hours lecture; 3 semester hours.

CEEN312L. SOIL MECHANICS LABORATORY. 1.0 Semester Hr.
Equivalent with EGGN363,
(I, II) Introduction to laboratory testing methods in soil mechanics. Classification, permeability, compressibility, shear strength. Co-requisites: CEEN312. 3 hours lab; 1 semester hour.

CEEN314. STRUCTURAL THEORY. 3.0 Semester Hrs.
Equivalent with EGGN342,
(I, II) Analysis of determinate and indeterminate structures for both forces and deflections. Influence lines, work and energy methods, moment distribution, matrix operations, computer methods. Prerequisite: CEEN311. 3 hours lecture; 3 semester hours.

CEEN330. ENGINEERING FIELD SESSION, ENVIRONMENTAL. 3.0 Semester Hrs.
Equivalent with EGGN335,
(S) The environmental module is intended to introduce students to laboratory and field analytical skills used in the analysis of an environmental engineering problem. Students will receive instruction on the measurement of water quality parameters (chemical, physical, and biological) in the laboratory and field. The student will use these skills to collect field data and analyze a given environmental engineering problem. Prerequisites: CEEN301. Three weeks in summer session; 9 hours lab; 3 semester hours.

CEEN331. ENGINEERING FIELD SESSION, CIVIL. 3.0 Semester Hrs.
Equivalent with EGGN234,
(S) The theory and practice of modern surveying. Lectures and hands-on field work teaches horizontal, vertical, and angular measurements and computations using traditional and modern equipment. Subdivision of land and applications to civil engineering practice, GPS and astronomic observations. Prerequisite: EDNS251, ENDS261, EDNS262 or CEEN267. Three weeks (6 day weeks) in summer field session; 9 hours lab; 3 semester hours.

CEEN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
Equivalent with EGGN340,EGGN340C,
(I,II,S) Supervised full-time engineering-related employment in which specific educational objectives are set and achieved. The co-op differs from a typical internship in both the length and scope of responsibilities. Students must meet with the CEE Co-op Advisor prior to enrolling to determine the appropriateness of the engagement, clarify the educational objectives, set expectations, and receive written approval for their specific Co-op program. This prior approval of the CEE Co-op Advisor and completion of paperwork with the Career Center is required prior to beginning the work portion of the program. The co-op occurs during academic fall or spring semester(s) and may overlap with a summer session, with a typical length of six months total. Prerequisite: Second semester sophomore status or above and a cumulative grade-point average of at least 2.00. 3.0 credit hours. This course is repeatable.

CEEN350. CIVIL AND CONSTRUCTION ENGINEERING MATERIALS. 3.0 Semester Hrs.
(I) This course deals with the nature and performance of civil engineering materials and evaluation of their physical and mechanical properties. This course focuses on materials used in construction and maintenance of building and infrastructure such as metals (steel and aluminum), aggregates, Portland cement, concrete, shotcrete, asphalt, wood, recycled materials, and composites. The course covers standards describing materials and tests for determining material properties and includes a lab component where students conduct tests, analyze the resulting data, and prepare technical reports. Laboratory tests include evaluation of behavior of civil engineering materials under a wide range of conditions. Prerequisites: CEEN311. 2 hours lecture; 3 hours lab, 3 semester hours.

CEEN360. INTRODUCTION TO CONSTRUCTION ENGINEERING. 3.0 Semester Hrs.
(II) Overview of the construction process for civil construction (spanning the building, transportation, and infrastructure sectors), including procurement methods and project delivery methods, codes, regulations, tests, standards, and Risk estimation and management. Construction methods and materials. Construction contracts, including drawings and specifications. Construction administration, including submittals, requests for information, change orders, special instructions, claims, disputes, arbitration, litigation, and project close-out. Project scheduling using the Critical Path Method. Construction project management. Construction safety and OSHA. Quantity takeoffs and construction estimating. Application of engineering analysis and design to construction projects. 3 hours lecture; 3 semester hours.

CEEN381. HYDROLOGY AND WATER RESOURCES ENGINEERING. 3.0 Semester Hrs.
Equivalent with CEEN481,ESGN459,
(II) This course introduces the principles of physical hydrology and fundamentals of water resources engineering. Topics include groundwater, surface water, precipitation, infiltration, evapotranspiration, sediment transport, flood and drought analysis, lake and reservoir analysis, water-resources planning, water quality engineering, stormwater management, and engineering design problems. Prerequisites: CEEN310. 3 hour lecture; 3 semester hours.

CEEN398. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN401. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.
(II) Which is more sustainable: paper vs plastic, hybrid vs electric vehicles? LCA is a powerful tool used to answer these questions; LCA quantifies the environmental sustainability of a product or process. Students will learn to conduct an LCA during a semester-long project of their choosing. At the end of the course students should be able to sit for the ACLCA professional LCACP certification exam. Prerequisite: Junior standing. 3 hours lecture; 3 semester hours.

CEEN405. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN460,
(S) Introduction to the use of numerical methods in the solution of problems encountered in engineering analysis and design, e.g. linear simultaneous equations (e.g. analysis of elastic materials, steady heat flow); roots of nonlinear equations (e.g. vibration problems, open channel flow); eigenvalue problems (e.g. natural frequencies, buckling and elastic stability); curve fitting and differentiation (e.g. interpretation of experimental data, estimation of gradients); integration (e.g. summation of pressure distributions, finite element properties, local averaging); ordinary differential equations (e.g. forced vibrations, beam bending). All course participants will receive source code consisting of a suite of numerical methods programs. Prerequisites: CSCI260 or CSCI261 or MATH307, MATH225. 3 hours lecture; 3 semester hours.

CEEN406. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN442,
(II) General theories of stress and strain; stress and strain transformations, principal stresses and strains, octahedral shear stresses, Hooke's law for isotropic material, and failure criteria. Introduction to elasticity and to energy methods. Torsion of noncircular and thin-walled members. Unsymmetrical bending and shear-center, curved beams, and beams on elastic foundations. Introduction to plate theory. Thick-walled cylinders and contact stresses. Prerequisites: CEEN311 or MEGN312; MATH225. 3 hours lecture; 3 semester hours.

CEEN410. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN448,
Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength and probabilistic methods. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisite: CEEN312. 3 hour lectures; 3 semester hours. Fall even years.

CEEN411. SOIL DYNAMICS. 3.0 Semester Hrs.
Equivalent with CEEN512,EGGN431,
(II) Soil Dynamics combines engineering vibrations with soil mechanics, analysis, and design. Students will learn to apply basic principles of dynamics towards the analysis and design of civil infrastructure systems when specific issues as raised by the inclusion of soil materials must be considered. Prerequisites: CEEN311, CEEN312, and MATH225. 3 hours lecture; 3 semester hours.

CEEN412. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with CEEN511,
(II) Systematic introduction of soil mechanics under partially saturated conditions. Topics include principles of seepage under variably saturated conditions, principle of the effective stress, shear strength theory, and hydraulic and mechanical properties. When this course is cross-listed and concurrent with CEEN511, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 lecture hours, 3 semester hours.

CEEN415. FOUNDATION ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN464,
(I, II) Techniques of subsoil investigation, types of foundations and foundation problems, selection of basis for design of foundation types. Open-ended problem solving and decision making. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN421. HIGHWAY AND TRAFFIC ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN435,
The emphasis of this class is on the multi-disciplinary nature of highway and traffic engineering and its application to the planning and design of transportation facilities. In the course of the class the students will examine design problems that will involve: geometric design, surveying, traffic operations, hydrology, hydraulics, elements of bridge design, statistics, highway safety, transportation planning, engineering ethics, soil mechanics, pavement design, economics, environmental science. 3 credit hours. Taught on demand.

CEEN423. SURVEYING FOR ENGINEERS AND INFRASTRUCTURE DESIGN PRACTICES. 3.0 Semester Hrs.
Equivalent with EGGN333,EGGN433,
(I) Applications of civil engineering skills using the engineer's level, total station, GPS receiver, and commercial software for field data collection, design, and layout of civil infrastructure including survey control, roadways, intersections, and utilities such as water and sewer. The course includes basic road design, horizontal design, vertical design, centerline layout, slope/cross section staking, earthwork volume calculations, engineering astronomy, and preparation of plan/profile drawings. Some discussion of concepts and mathematics of applying GPS data to engineering projects and the principles of map projections (Mercator, Lambert, UTM, State Plane, etc.) and coordinate systems such as (North American Datum) NAD '27, NAD '83, and other reference networks is included. Prerequisite: CEEN331. 2 hours lecture; 8-9 field work days; 3 semester hours.

CEEN430. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN441,
(II) Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. Prerequisite: CEEN314. 3 hour lectures; 3 semester hours.

CEEN433. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN533,
(II) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN533, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisite: CEEN314. 3 lecture hours, 3 semester hours.

CEEN440. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN447,
(II) The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Prerequisite: CEEN311 or equivalent. 3 hours lecture: 3 semester hours. Spring odd years.

CEEN441. INTRODUCTION TO THE SEISMIC DESIGN OF STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN494,
(I) This course provides students with an introduction to seismic design as it relates to structures. Students will become familiar with the sources of seismic disturbances, the physics of seismic energy transmission, and the relationship between ground disturbance and the resulting forces experienced by structures. The theory and basis for existing building code provisions relating to seismic design of structures will be introduced. Building code requirements and design methodologies will be examined and applied. Prerequisites: CEEN443, or CEEN445, or CEEN440. 3 hours lecture; 3 semester hours.

CEEN443. DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN444,
(I, II) To learn application and use the American Institute of Steel Construction (AISC) Steel Construction Manual. Course develops an understanding of the underlying theory for the design specifications. Students learn basic steel structural member design principles to select the shape and size of a structural member. The design and analysis of tension members, compression members, flexural members, and members under combined loading is included, in addition to basic bolted and welded connection design. Prerequisite: CEEN314. 3 hours lecture; 3 semester hours.

CEEN445. DESIGN OF REINFORCED CONCRETE STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN445,
(I, II) This course provides an introduction to the materials and principles involved in the design of reinforced concrete. It will allow students to develop an understanding of the fundamental behavior of reinforced concrete under compressive, tensile, bending, and shear loadings, and gain a working knowledge of strength design theory and its application to the design of reinforced concrete beams, columns, slabs, and footings. Prerequisite: CEEN314. 3 hours lecture; 3 semester hours.

CEEN461. FUNDAMENTALS OF ECOLOGY. 3.0 Semester Hrs.
Equivalent with ESGN401,
(II). Biological and ecological principles discussed and industrial examples of their use given. Analysis of ecosystem processes, such as erosion, succession, and how these processes relate to engineering activities, including engineering design and plant operation. Criteria and performance standards analyzed for facility siting, pollution control, and mitigation of impacts. North American ecosystems analyzed. Concepts of forestry, range, and wildlife management integrated as they apply to all of the above. Three to four weekend trips will be arranged during the semester. 3 lecture hours, 3 semester hours.

CEEN470. WATER AND WASTEWATER TREATMENT PROCESSES. 3.0 Semester Hrs.
Equivalent with BELS453,EGGN453,ESGN453,
(I) The goal of this course is to familiarize students with the unit operations and processes involved in water and wastewater treatment. This course will focus on the physical, chemical, and biological processes for water and wastewater treatment and reclamation. Treatment objectives, process theory, and practice are considered in detail. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN471. WATER AND WASTEWATER TREATMENT SYSTEMS ANALYSIS AND DESIGN. 3.0 Semester Hrs.
(II) The goal of this course is to familiarize students with the design of domestic and industrial water and wastewater treatment systems. This course will focus on the combination of physical, chemical, and biological processes and technologies to form a water or wastewater treatment system. Source water quality, treatment objectives, water reuse, multi-barrier approaches, and water and energy efficiency are considered in detail. Prerequisites: CEEN470, or CEEN570, or other water or wastewater treatment design courses (for graduate students enrolled in this course). 3 hours lecture; 3 semester hours.

CEEN472. ONSITE WATER RECLAMATION AND REUSE. 3.0 Semester Hrs.
Equivalent with ESGN460,
(II). Appropriate solutions to water and sanitation in the U.S. and globally need to be effective in protecting public health and preserving water quality while also being acceptable, affordable and sustainable. Onsite and decentralized systems have the potential to achieve these goals in rural areas, peri-urban developments, and urban centers in small and large cities. Moreover they can improve water use efficiency, conserve energy and enable distributed energy generation, promote green spaces, restore surface waters and aquifers, and stimulate new green companies and jobs. A growing array of approaches, devices and technologies have evolved that include point-of-use water purification, waste source separation, conventional and advanced treatment units, localized natural treatment systems, and varied resource recovery and recycling options. This course will focus on the engineering selection, design, and implementation of onsite and decentralized systems for water reclamation and reuse. Topics to be covered include process analysis and system planning, water and waste stream attributes, water and resource conservation, confined unit and natural system treatment technologies, effluent collection and clustering, recycling and reuse options, and system management. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN473. HYDRAULIC PROBLEMS. 3.0 Semester Hrs.
Equivalent with EGGN451,
(I,II) Review of fundamentals, forces on submerged surfaces, buoyancy and flotation, gravity dams, weirs, steady flow in open channels, backwater curves, hydraulic machinery, elementary hydrodynamics, hydraulic structures. Prerequisites: CEEN310. 3 hours lecture; 3 semester hours.

CEEN474. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
Equivalent with ESGN462,
(I) The course objective is to put the student into the shoes of a plant manager having process responsibility for waste minimization, focusing on recycling. Emphasis is on proven and emerging solutions, especially those associated with heavy metals. Waste minimization generally requires a solid understanding of alternative raw materials and process technologies, in combination with creativity and sensitivity to economics. Prerequisites: Senior standing 3 hours lecture; 3 semester hours.

CEEN475. SITE REMEDIATION ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN457,ESGN457,
(I, II) This course describes the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. Common isolation and containment and in-situ and ex-situ treatment technology will be covered. Computerized decision-support tools will be used and case studies will be presented. Prerequisites: CHGN121. 3 hours lecture; 3 semester hours.

CEEN476. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.
Equivalent with ESGN463,
(II) The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. Prerequisite: CEEN301 or CEEN302. 3 hours lecture; 3 semester hours.

CEEN477. SUSTAINABLE ENGINEERING DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN490,
(I) This course is a comprehensive introduction into concept of sustainability and sustainable development from an engineering point of view. It involves the integration of engineering and statistical analysis through a Life Cycle Assessment tool, allowing a quantitative, broad-based consideration any process or product design and their respective impacts on environment, human health and the resource base. The requirements for considering social implications are also discussed. Prerequisites: Senior or graduate standing; 3 hours lecture, 3 semester hours.

CEEN479. AIR POLLUTION. 3.0 Semester Hrs.
(II) This course familiarizes students with the basic physics, chemistry and biology of major air pollutants, related health impacts, and engineered approaches used to mitigate the effects of common air pollutants. This course is also designed to provide a solid foundation in air pollution topic areas found on the FEE or PE exam. Critical US air pollution legislation is discussed. The sources of particulate and gaseous pollutants from both stationary and mobile sources, associated key chemical reactions, and approaches for control are considered. Indoor air pollution and the Gaussian dispersion model for air pollutants are discussed. Prerequisite: CEEN302. 3 hours lecture; 3 semester hours.

CEEN480. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with ESGN440,
(I) This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: CEEN301. 3 hours lecture; 3 semester hours.

CEEN482. HYDROLOGY AND WATER RESOURCES LABORATORY. 3.0 Semester Hrs.
(I) This course introduces students to the collection, compilation, synthesis and interpretation of data for quantification of the components of the hydrologic cycle, including precipitation, evaporation, infiltration, and runoff. Students will use hydrologic variables and parameters to evaluate watershed processes and behavior. Students will also survey and apply measurement techniques necessary for watershed studies. Advanced topics include development, construction, and application of analytical models for selected problems in hydrology and water resources. Prerequisite: CEEN381. 2 hours lecture; 3 hours lab; 3 semester hours.

CEEN492. ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with CEEN592,ESGN490,ESGN502,PEGN530,
(I) Specially designed for the needs of the environmental quality engineer, scientist, planner, manager, government regulator, consultant, or advocate. Highlights include how our legal system works, environmental law fundamentals, all major US EPA/state enforcement programs, the National Environmental Policy Act, air and water pollutant laws, risk assessment and management, and toxic and hazardous substance laws (RCRA, CERCLA, TSCA, LUST, etc). Prerequisites: CEEN301 or CEEN302. 3 hours lecture; 3 semester hours.

CEEN498. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CEEN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CEEN501. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.
(II) Which is more sustainable: paper vs plastic, hybrid vs electric vehicles? LCA is a powerful tool used to answer these questions; LCA quantifies the environmental sustainability of a product or process. Students will learn to conduct an LCA during a semester-long project of their choosing. At the end of the course students should be able to sit for the ACLCA professional LCACP certification exam. 3 hours lecture; 3 semester hours.

CEEN505. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN560,
(S) Introduction to the use of numerical methods in the solution of commonly encountered problems of engineering analysis. Structural/solid analysis of elastic materials (linear simultaneous equations); vibrations (roots of nonlinear equations, initial value problems); natural frequency and beam buckling (eigenvalue problems); interpretation of experimental data (curve fitting and differentiation); summation of pressure distributions (integration); beam deflections (boundary value problems). All course participants will receive source code of all the numerical methods programs published in the course textbook which is coauthored by the instructor. Prerequisite: MATH225. 3 hours lecture; 3 semester hours.

CEEN506. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN542,
(II) A course combining finite element theory with practical programming experience in which the multidisciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple ?structural? elements, beams on elastic foundations, solid elasticity, steady state analysis and transient analysis. Some of the applications will lie in the general area of geomechanics, reflecting the research interests of the instructor. Students get a copy of all the source code published in the course textbook. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN510. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN548,
Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength, failure criteria and constitutive models for soil. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisites: A first course in soil mechanics. 3 Lecture Hours, 3 semester hours. Fall even years.

CEEN511. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGES533,EGGN533,
The focus of this course is on soil mechanics for unsaturated soils. It provides an introduction to thermodynamic potentials in partially saturated soils, chemical potentials of adsorbed water in partially saturated soils, phase properties and relations, stress state variables, measurements of soil water suction, unsaturated flow laws, measurement of unsaturated permeability, volume change theory, effective stress principle, and measurement of volume changes in partially saturated soils. The course is designed for seniors and graduate students in various branches of engineering and geology that are concerned with unsaturated soil?s hydrologic and mechanics behavior. When this course is cross-listed and concurrent with CEEN412, students that enroll in CEEN511 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 hours lecture; 3 semester hours. Spring even years.

CEEN512. SOIL BEHAVIOR. 3.0 Semester Hrs.
Equivalent with EGES534,EGGN534,
(I) The focus of this course is on interrelationships among the composition, fabric, and geotechnical and hydrologic properties of soils that consist partly or wholly of clay. The course will be divided into two parts. The first part provides an introduction to the composition and fabric of natural soils, their surface and pore-fluid chemistry, and the physico-chemical factors that govern soil behavior. The second part examines what is known about how these fundamental characteristics and factors affect geotechnical properties, including the hydrologic properties that govern the conduction of pore fluid and pore fluid constituents, and the geomechanical properties that govern volume change, shear deformation, and shear strength. The course is designed for graduate students in various branches of engineering and geology that are concerned with the engineering and hydrologic behavior of earth systems, including geotechnical engineering, geological engineering, environmental engineering, mining engineering, and petroleum engineering. When this course is cross-listed and concurrent with CEEN411, students that enroll in CEEN512 will complete additional and/or more complex assignments. Prerequisites: CEEN361 Soil Mechanics. 3 hours lecture; 3 semester hours.

CEEN513. ADVANCED GEOMATERIAL MECHANICS. 4.0 Semester Hrs.
(I) This course deals with the classification and engineering behavior of soil and rock materials as well as materials used in underground construction such as structural steel, aggregates, cement, timber, concrete, shotcrete, accelerators and ground conditioning agents. This course presents an advanced treatment of soil and rock mechanics with focus on the following topics: Index and classification properties of soils, Physical properties and classification of intact rock and rock masses, Fluid flow in soils and rocks, Compressibility of soils and rocks, Failure theories and strength testing of soils and rocks, Shear strength of soils and rocks, Stresses and deformations around underground openings, Laboratory and field methods for evaluation of soil and rock properties, and Analytical and empirical approaches for the design and construction of structures in soil and rock materials. Prerequisites: Undergraduate degree in a pertinent discipline of engineering or equivalent and undergraduate level knowledge of material behavior. Co-requisites: GEGN561. 4 hours lecture; 4 semester hours.

CEEN514. SOIL DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN531,
(II) Dynamic phenomena in geotechnical engineering, e.g., earthquakes, pile and foundation vibrations, traffic, construction vibrations; behavior of soils under dynamic loading, e.g., small, medium and large strain behavior, soil liquefaction; wave propagation through soil and rock; laboratory and field techniques to assess dynamic soil properties; analysis and design of shallow and deep foundations subjected to dynamic loading; analysis of construction vibrations. Prerequisites: CEEN312, MEGN315, CEEN415. 3 hours lecture; 3 semester hours.

CEEN515. HILLSLOPE HYDROLOGY AND STABILITY. 3.0 Semester Hrs.
Equivalent with EGGN536,
(I) Introduction of shallow landslide occurrence and socio-economic dynamics. Roles of unsaturated flow and stress in shallow landslides. Slope stability analysis based on unsaturated effective stress conceptualization. Computer modeling of unsaturated flow and stress distributions in hillslope. Prediction of precipitation induced shallow landslides. Prerequisite: CEEN312. 3 hours lecture; 3 semester hours.

CEEN520. EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS. 3.0 Semester Hrs.
(II) Analysis, design, construction and monitoring of earth retaining structures and support of excavations used for permanent and temporary support of transportation facilities, bridges, underground structures and tunnels, shafts, waterfront structures, earth slopes and embankments. Includes gravity, semi-gravity, cantilevered, anchored, geosynthetic and ground improvement walls. Addresses fundamental geomechanics required for analysis and design, ASD (allowable stress design) and LRFD (load resistance factor design) design techniques, and construction techniques. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 semester hours.

CEEN523. UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND. 4.0 Semester Hrs.
(II) Design and construction of water, wastewater, transportation and utility tunnels, underground space and shafts/excavations in soft ground conditions (soil and weak rock). Addresses geotechnical site characterization, selection of design parameters, stability and deformation analysis of the ground and overlying structures, and construction methods. Includes design of temporary and permanent structural ground support according to ASD (allowable stress design) and LRFD (load resistance factor design) approaches, and design of ground improvement schemes and instrumentation/monitoring approaches to mitigate risk. This course requires post-graduate level knowledge of soil mechanics, fundamental understanding of engineering geology, and an undergraduate level knowledge of structural analysis and design. Prerequisites: CEEN513 and GEGN468. Co-requisites: GEGN562. 4 hours lecture; 4 semester hours.

CEEN530. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN541,
(I) Introduction to advanced structural analysis concepts. Nonprismatic structures. Arches, Suspension and cable-stayed bridges. Structural optimization. Computer Methods. Structures with nonlinear materials. Internal force redistribution for statically indeterminate structures. Graduate credit requires additional homework and projects. Prerequisite: CEEN314. 3 hour lectures, 3 semester hours.

CEEN531. STRUCTURAL DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN557,
An introduction to the dynamics and earthquake engineering of structures is provided. Subjects include the analysis of linear and nonlinear single-degree and multi-degree of freedom structural dynamics. The link between structural dynamics and code-based analysis and designs of structures under earthquake loads is presented. he focus applicaitons of the course include single story and multi-story buildings, and other types of sructures that under major earthquake may respond in the inelastic range. Prerequisites: CEEN314 Structural Theory. 3 semester hours.

CEEN533. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN433,
(II) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN433, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisites: CEEN314 Elementary Structural Theory. 3 lecture hours, 3 semester hours.

CEEN540. ADVANCED DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN549,
The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. Prerequisite: CEEN443 or equivalent. 3 hours lecture; 3 semester hours. Spring even years.

CEEN541. DESIGN OF REINFORCED CONCRETE STRUCTURES II. 3.0 Semester Hrs.
Equivalent with EGGN556,
Advanced problems in the analysis and design of concrete structures, design of slender columns; biaxial bending; two-way slabs; strut and tie models; lateral and vertical load analysis of multistory buildings; introduction to design for seismic forces; use of structural computer programs. Prerequisite: CEEN445. 3 hour lectures, 3 semester hours. Delivered in the spring of even numbered years.

CEEN542. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN547,
The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Connection design and advanced seismic analysis principles are introduced. Prerequisite: CEEN314 or equivalent. 3 hours lecture; 3 semester hours. Spring odd years.

CEEN543. CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS. 3.0 Semester Hrs.
Equivalent with EGGN558,
This course presents the fundamentals of concrete bridge analysis and design including conceptual design, superstructure analysis, AASHTO-LRFD bridge specifications, flat slab bridge design, and pre-stressed concrete bridge design. The course is presented through the complete design of the superstructure of an example bridges. At the conclusion of the course, students will be able to analyze and design simple, but complete concrete bridge superstructures. Prerequisites: CEEN445, Design of Reinforced Concrete Structure. 3 hours lecture; 3 semester hours.

CEEN544. STRUCTURAL PRESERVATION OF EXISTING AND HISTORIC BUILDINGS. 3.0 Semester Hrs.
(I, II) A broad discussion of historic structural systems in the United States, including stone and brick masonry, terra cotta, timber, cast and wrought iron, early steel, and early concrete. Combines research of historic manuals with contemporary analysis. Introduces nondestructive tests for historic structures. Enables prediction of deterioration mechanisms and structural deficiencies. Synthesizes structural retrofit solutions with preservation philosophy and current building codes. Emphasizes the engineer?s role in stewardship of historic buildings. Prerequisites: CEEN443 and CEEN445. 3 hours lecture and discussion; 3 semester hours.

CEEN545. STEEL BRIDGE DESIGN. 3.0 Semester Hrs.
(I, II, S) Students are introduced to, and will develop an understanding of, the theory, analysis, and AASHTO code requirements for the design of steel bridge superstructures. The students will become familiar with bridge types, required loadings, composite action, plate girder design, and the Load and Resistance Factor Design method. The students will recognize the design requirements for a steel bridge superstructure and perform calculations for member loads and the loadings it transfers to the substructure. Prerequisites: CEEN443. 3 hours lecture; 3 semester hours.

CEEN546. STATISTICAL METHODS FOR RELIABILITY AND ENGINEERING DESIGN. 3.0 Semester Hrs.
(I, II, S) The course will introduce methods and principles that help quantifying the effects of uncertainty in the performance prediction of civil infrastructure systems. Students will learn to apply quantitative risk analysis and modeling approaches relevant to design problems in civil engineering. The course emphasizes that the systematic treatment of uncertainty and risk quantification are essential for adequate engineering planning, design, and operation of systems. The statistical approaches fundamental to engineering design and theory of reliability in structural and underground infrastructure design will be the focus of the course and examples. 3 hours lecture; 3 semester hours.

CEEN550. PRINCIPLES OF ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs.
Equivalent with ESGN500,
This course provides an introduction to chemical equilibria in natural waters and engineered systems. Topics covered include chemical thermodynamics and kinetics, acid/base chemistry, open and closed carbonate systems, precipitation reactions, coordination chemistry, adsorption and redox reactions. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN551. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs.
Equivalent with ESGN555,
A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CEEN552. CHEMISTRY OF THE SOIL / WATER INTERFACE. 3.0 Semester Hrs.
Equivalent with ESGN525,
The fate of many elements in the soil/water environment is regulated by sorption reactions. The content of this course focuses on the physical chemistry of reactions occurring at the soil-particle/water interface. The emphasis is on the use of surface complexation models to interpret solute sorption at the particle/water interface. Prerequisites: CEEN550. 3 hours lecture; 3 semester hours.

CEEN553. ENVIRONMENTAL RADIOCHEMISTRY. 3.0 Semester Hrs.
Equivalent with ESGN510,
This course covers the phenomena of radioactivity (e.g., modes of decay, methods of detection and biological effects) and the use of naturally occurring and artificial radionuclides as tracers for environmental processes. Discussions of tracer applications will range from oceanic trace element scavenging to contaminant transport through groundwater aquifers. Prerequisites: CEEN 550. 3 hours lecture; 3 semester hours.

CEEN555. LIMNOLOGY. 3.0 Semester Hrs.
Equivalent with ESGN513,
This course covers the natural chemistry, physics, and biology of lakes as well as some basic principles concerning contamination of such water bodies. Topics include heat budgets, water circulation and dispersal, sedimentation processes, organic compounds and their transformations, radionuclide limnochronology, redox reactions, metals and other major ions, the carbon dioxide system, oxygen, nutrients; planktonic, benthic and other communities, light in water and lake modeling. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN556. MINING AND THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with ESGN556,
The course will cover many of the environmental problems and solutions associated with each aspect of mining and ore dressing processes. Mining is a complicated process that differs according to the type of mineral sought. The mining process can be divided into four categories: Site Development; Extraction; Processing; Site Closure. Procedures for hard rock metals mining; coal mining; underground and surface mining; and in situ mining will be covered in relation to environmental impacts. Beneficiation, or purification of metals will be discussed, with cyanide and gold topics emphasized. Site closure will be focused on; stabilization of slopes; process area cleanup; and protection of surface and ground water. After discussions of the mining and beneficiation processes themselves, we will look at conventional and innovative measures to mitigate or reduce environmental impact.

CEEN558. ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES. 3.0 Semester Hrs.
Equivalent with ESGN511,
The stewardship of nuclear resources spans the entire nuclear fuel cycle, which includes mining and milling through chemical processing on the front end of the materials life cycle. On the back end, stewardship continues from materials removal from the power plant during re-fueling or facility decommissioning, through storage, recycling and disposal, as well as the management of activated or contaminated materials generated during facility decommissioning. Each stage in the fuel cycle has a different risk of public exposure through different pathways and the presence of different isotopes. These risks are an integral part in considering the long-term efficacy of nuclear as an energy alternative. Furthermore, nuclear energy has long been vilified in public opinion forums via emotional responses. Stewardship extends beyond quantification of risks to the incorporation and communication of these risks and the associated facts regarding nuclear power to the public at large. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

CEEN560. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with ESGN586,
This course explores the diversity of microbiota in a few of the countless environments of our planet. Topics include microbial ecology (from a molecular perspective), microbial metabolism, pathogens, extreme environments, engineered systems, oxidation / reduction of metals, bioremediation of both organics and inorganics, microbial diversity, phylogenetics, analytical tools and bioinformatics. The course has an integrated laboratory component for applied molecular microbial ecology to learn microscopy, DNA extraction, PCR, gel electrophoresis, cloning, sequencing, data analysis and bioinformatic applications. Prerequisite: College Biology and/or CHGC562, CHGC563 or equivalent and enrollment in the ESE graduate program. 3 hours lecture, some field trips; 3 semester hours.

CEEN562. ENVIRONMENTAL GEOMICROBIOLOGY. 3.0 Semester Hrs.
Equivalent with BELS596,ESGN596,
(II) This course explores the functional activities and biological significance of microorganisms in geological and engineered systems with a focus on implications to water resources. Topics include: microorganisms as geochemical agents of change, mechanisms and thermodynamics of microbial respiration, applications of analytical, material science and molecular biology tools to the field, and the impact of microbes on the fate and transport of problematic water pollutants. Emphasis will be placed on critical analysis and communication of peer-reviewed literature on these topics. 3 hours lecture and discussion; 3 semester hours.

CEEN564. ENVIRONMENTAL TOXICOLOGY. 3.0 Semester Hrs.
Equivalent with BELS545,ESGN545,
This course provides an introduction to general concepts of ecology, biochemistry, and toxicology. The introductory material will provide a foundation for understanding why, and to what extent, a variety of products and by-products of advanced industrialized societies are toxic. Classes of substances to be examined include metals, coal, petroleum products, organic compounds, pesticides, radioactive materials, and others. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN565. AQUATIC TOXICOLOGY. 3.0 Semester Hrs.
Equivalent with BELS544,ESGN544,
This course provides an introduction to assessment of the effects of toxic substances on aquatic organisms, communities, and ecosystems. Topics include general toxicological principles, water quality standards, sediment quality guidelines, quantitative structure-activity relationships, single species and community-level toxicity measures, regulatory issues, and career opportunities. The course includes hands-on experience with toxicity testing and subsequent data reduction. Prerequisite: none. 2.5 hours lecture; 1 hour laboratory; 3 semester hours.

CEEN566. MICROBIAL PROCESSES, ANALYSIS AND MODELING. 3.0 Semester Hrs.
Equivalent with BELS541,ESGN541,
Microorganisms facilitate the transformation of many organic and inorganic constituents. Tools for the quantitative analysis of microbial processes in natural and engineered systems will be presented. Stoichiometries, energetics, mass balances and kinetic descriptions of relevant microbial processes allow the development of models for specific microbial systems. Simple analytical models and complex models that require computational solutions will be presented. Systems analyzed include suspended growth and attached growth reactors for municipal and industrial wastewater treatment as well as in-stu bioremediation and bioenergy systems. 3 hours lecture; 3 semester hours.

CEEN570. WATER AND WASTEWATER TREATMENT. 3.0 Semester Hrs.
Equivalent with ESGN504,
Unit operations and processes in environmental engineering are discussed in this course, including physical, chemical, and biological treatment processes for water and wastewater. Treatment objectives, process theory, and practice are considered in detail. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN571. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE. 3.0 Semester Hrs.
Equivalent with ESGN506,
This course presents issues relating to theory, design, and operation of advanced water and wastewater treatment unit processes and water reuse systems. Topics include granular activated carbon (GAC), advanced oxidation processes (O3/H2O2), UV disinfection, pressure-driven, current-driven, and osmotic-driven membranes (MF, UF, NF, RO, electrodialysis, and forward osmosis), and natural systems such as riverbank filtration (RBF) and soil-aquifer treatment (SAT). The course is augmented by CEEN571L offering hands-on experience using bench- and pilot-scale unit operations. Prerequisite: CEEN470 or CEEN471 or CEEN570 or CEEN572. 3 hours lecture; 3 semester hours.

CEEN571L. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE - LABORATORY. 1.0 Semester Hr.
Equivalent with ESGN506L,
This course provides hands-on experience using bench- and pilotscale unit operations and computer exercises using state-ofthe- art software packages to design advanced water treatment unit processes. Topics include adsorption processes onto powdered and granular activated carbon, low-pressure membrane processes (microfiltration, ultrafiltration), and highpressure and current-driven membrane processes (nanofiltration, reverse osmosis, and electrodialysis). The course is a highly recommended component of CEEN571 and meets 5 - 6 times during the semester to support the work in CEEN571. Co- or Pre-requisite: CEEN571. 1 semester hour.

CEEN572. ENVIRONMENTAL ENGINEERING PILOT PLANT LABORATORY. 4.0 Semester Hrs.
Equivalent with ESGN530,
This course provides an introduction to bench and pilot-scale experimental methods used in environmental engineering. Unit operations associated with water and wastewater treatment for real-world treatment problems are emphasized, including multi-media filtration, oxidation processes, membrane treatment, and disinfection processes. Investigations typically include: process assessment, design and completion of bench- and pilot-scale experiments, establishment of analytical methods for process control, data assessment, upscaling and cost estimation, and project report writing. Projects are conducted both at CSM and at the City of Golden Water Treatment Pilot Plant Laboratory. Prerequisites: CEEN550 and CEEN570. 6 hours laboratory; 4 semester hours.

CEEN573. RECLAMATION OF DISTURBED LANDS. 3.0 Semester Hrs.
Equivalent with ESGN552,
Basic principles and practices in reclaiming disturbed lands are considered in this course, which includes an overview of present legal requirements for reclamation and basic elements of the reclamation planning process. Reclamation methods, including recontouring, erosion control, soil preparation, plant establishment, seed mixtures, nursery stock, and wildlife habitat rehabilitation, will be examined. Practitioners in the field will discuss their experiences. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN574. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
Equivalent with ESGN562,
This course will examine, using case studies, ways in which industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisite: CEEN550. 3 hours lecture; 3 semester hours.

CEEN575. HAZARDOUS WASTE SITE REMEDIATION. 3.0 Semester Hrs.
Equivalent with ESGN575,
This course covers remediation technologies for hazardous waste contaminated sites, including site characteristics and conceptual model development, remedial action screening processes, and technology principles and conceptual design. Institutional control, source isolation and containment, subsurface manipulation, and in situ and ex situ treatment processes will be covered, including unit operations, coupled processes, and complete systems. Case studies will be used and computerized tools for process selection and design will be employed. Prerequisite: CEEN550 and CEEN580. 3 hours lecture; 3 semester hours.

CEEN575L. HAZARDOUS WASTE SITE REMEDIATION: TREATABILITY TESTING. 1.0 Semester Hr.
Equivalent with ESGN575L,
This laboratory module is designed to provide hands-on experience with treatability testing to aid selection and design of remediation technologies for a contaminated site. The course will be comprised of laboratory exercises in Coolbaugh Hall and possibly some field site work near CSM. Pre-requisite: CEEN575. 2 hours laboratory; 1 semester hour.

CEEN576. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.
Equivalent with ESGN563,
The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. 3 hours lecture; 3 semester hours.

CEEN580. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with ESGN503,
This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater, and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN581. WATERSHED SYSTEMS MODELING. 3.0 Semester Hrs.
Equivalent with ESGN527,
Introduction to surface water modeling, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis. Course is heavy on application of models across a range of diverse watersheds for streamflow and snowmelt predictions. In general, theoretical topics are covered in the first meeting each week, followed by hands-on application of concepts and models in the second meeting. Laptops and student Matlab licenses will be required for in-class activities. Prerequisite: none. 3 hours lecture per week; 3 semester hours.

CEEN582. MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with ESGN528,
This is an advanced graduate-level course designed to provide students with hands-on experience in developing, implementing, testing, and using mathematical models of environmental systems. The course will examine why models are needed and how they are developed, tested, and used as decision-making or policy-making tools. Typical problems associated with environmental systems, such as spatial and temporal scale effects, dimensionality, variability, uncertainty, and data insufficiency, will be addressed. The development and application of mathematical models will be illustrated using a theme topic such as Global Climate Change, In Situ Bioremediation, or Hydrologic Systems Analysis. Prerequisites: CEEN580 and knowledge of basic statistics and computer programming. 3 hours lecture; 3 semester hours.

CEEN583. SURFACE WATER QUALITY MODELING. 3.0 Semester Hrs.
Equivalent with ESGN520,
This course will cover modeling of water flow and quality in rivers, lakes, and reservoirs. Topics will include introduction to common analytical and numerical methods used in modeling surface water flow, water quality, modeling of kinetics, discharge of waste water into surface systems, sedimentation, growth kinetics, dispersion, and biological changes in lakes and rivers. Prerequisites: CEEN480 or CEEN580 recommended. 3 hours lecture; 3 semester hours.

CEEN584. SUBSURFACE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.
Equivalent with ESGN522,
This course will investigate physical, chemical, and biological processes governing the transport and fate of contaminants in the saturated and unsaturated zones of the subsurface. Basic concepts in fluid flow, groundwater hydraulics, and transport will be introduced and studied. The theory and development of models to describe these phenomena, based on analytical and simple numerical methods, will also be discussed. Applications will include prediction of extents of contaminant migration and assessment and design of remediation schemes. Prerequisites: CEEN580. 3 hours lecture; 3 semester hours.

CEEN589. WATER SUSTAINABILITY AND ENERGY PRODUCTION: CURRENT SCIENCE AND PRACTICE. 1.0 Semester Hr.
(II) This course is designed to provide students with valuable communication and professional skills while exploring in depth the topic of joint sustainability of water and unconventional petroleum energy production. A survey of current literature combined with key speakers will introduce the students to the field, while class sessions and practical exercises will help develop important communication, research, and interpersonal skills needed for future professionals. Course curriculum includes specific topics such as speaking/writing for a variety of audiences and critical thinking and analysis. This course is required for all ConocoPhillips - WE2ST Fellows, but is also open to any interested graduate students. 1 hour seminar; 1 semester hour.

CEEN590. CIVIL ENGINEERING SEMINAR. 1.0 Semester Hr.
(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

CEEN591. ENVIRONMENTAL PROJECT MANAGEMENT. 3.0 Semester Hrs.
Equivalent with ESGN571,
This course investigates environmental project management and decision making from government, industry, and contractor perspectives. Emphasis is on (1) economics of project evaluation; (2) cost estimation methods; (3) project planning and performance monitoring; (4) and creation of project teams and organizational/communications structures. Extensive use of case studies. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN592. ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with CEEN492,ESGN490,ESGN502,PEGN530,
This is a comprehensive introduction to U.S. Environmental Law, Policy, and Practice, especially designed for the professional engineer, scientist, planner, manager, consultant, government regulator, and citizen. It will prepare the student to deal with the complex system of laws, regulations, court rulings, policies, and programs governing the environment in the USA. Course coverage includes how our legal system works, sources of environmental law, the major USEPA enforcement programs, state/local matching programs, the National Environmental Policy Act (NEPA), air and water pollution (CAA, CWA), EPA risk assessment training, toxic/hazardous substances laws (RCRA, CERCLA, EPCRA, TSCA, LUST, etc.), and a brief introduction to international environmental law. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN593. ENVIRONMENTAL PERMITTING AND REGULATORY COMPLIANCE. 3.0 Semester Hrs.
Equivalent with ESGN593,
The purpose of this course is to acquaint students with the permit writing process, developing information requirements for permit applications, working with ambiguous regulations, negotiating with permit writers, and dealing with public comment. In addition, students will develop an understanding of the process of developing an economic and legally defensible regulatory compliance program. Prerequisite: CEEN592. 3 hours lecture; 3 semester hours.

CEEN594. RISK ASSESSMENT. 3.0 Semester Hrs.
Equivalent with ESGN501,
This course evaluates the basic principles, methods, uses, and limitations of risk assessment in public and private sector decision making. Emphasis is on how risk assessments are made and how they are used in policy formation, including discussion of how risk assessments can be objectively and effectively communicated to decision makers and the public. Prerequisite: CEEN592 and one semester of statistics. 3 hours lecture; 3 semester hours.

CEEN595. ANALYSIS OF ENVIRONMENTAL IMPACT. 3.0 Semester Hrs.
Equivalent with ESGN591,
Techniques for assessing the impact of mining and other activities on various components of the ecosystem. Training in the procedures of preparing Environmental Impact Statements. Course will include a review of pertinent laws and acts (i.e. Endangered Species Act, Coordination Act, Clean Air Act, etc.) that deal with environmental impacts. Prerequisite: none. 3 hours lecture, some field trips; 3 semester hours.

CEEN596. ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR. 0.0 Semester Hrs.
Equivalent with ESGN590,
Research presentations covering current research in a variety of environmental topics.

CEEN598. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN610. INTERNATIONAL ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with ESGN602,
The course covers an introductory survey of International Environmental Law, including multi-nation treaties, regulations, policies, practices, and politics governing the global environment. It surveys the key issues of sustainable development, natural resources projects, transboundary pollution, international trade, hazardous waste, climate change, and protection of ecosystems, wildlife, and human life. New international laws are changing the rules for engineers, project managers, scientists, teachers, businesspersons, and others both in the US and abroad, and this course is especially designed to keep professionals fully, globally informed and add to their credentials for international work. Prerequisites: CEEN592. 3 hours lecture; 3 semester hours.

CEEN611. MULTIPHASE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.
Equivalent with ESGN622,
Principles of multiphase and multicomponent flow and transport are applied to contaminant transport in the unsaturated and saturated zones. Focus is on immiscible phase, dissolved phase, and vapor phase transport of low solubility organic contaminants in soils and aquifer materials. Topics discussed include: capillarity, interphase mass transfer, modeling, and remediation technologies. Prerequisites: CEEN550 or equivalent, CEEN580 or CEEN584 or equivalent. 3 hours lecture; 3 semester hours.

CEEN698. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN699. ADVANCED INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with EGGN707C,ESGN707,
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

COMMUNICATIONS (LICM)

LICM198. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LICM298. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LICM501. PROFESSIONAL ORAL COMMUNICATION. 1.0 Semester Hr.
A five-week course which teaches the fundamentals of effectively preparing and presenting messages. "Hands-on" course emphasizing short (5- and 10-minute) weekly presentations made in small groups to simulate professional and corporate communications. Students are encouraged to make formal presentations which relate to their academic or professional fields. Extensive instruction in the use of visuals. Presentations are rehearsed in class two days prior to the formal presentations, all of which are video-taped and carefully evaluated. 1 hour lecture/lab; 1 semester hour.

COMPUTER SCIENCE (CSCI)

CSCI101. INTRODUCTION TO COMPUTER SCIENCE. 3.0 Semester Hrs.
(I, II) An introductory course to the building blocks of Computer Science. Topics include conventional computer hardware, data representation, the role of operating systems and networks in modern computing, algorithm design, privacy and information security, data science, artificial intelligence, and computer ethics. A popular procedural programming language will be learned by students and programming assignments will explore ideas in algorithm development, optimization, and data manipulation. 3 hours lecture; 3 semester hours.

CSCI102. INTRODUCTION TO COMPUTER SCIENCE - LAB. 1.0 Semester Hr.
(I, II) This course is a 1-credit hour optional lab course for CSCI 101 that offers an opportunity for new programmers to learn the Python programming language. Python is a powerful interpreted programming language with a simple syntax and a large set of libraries. While Python is an easy language for beginner programmers to learn, it is a language that is widely used in many scientific areas (e.g., data science). This lab course will introduce students to basic programming concepts: conditionals, loops, lists, strings, file input/output, functions, and objects. Take this course with CSCI 101 to either create a 4-credit hour distributed science elective or gain more experience with algorithmic design/ programming in Python. 1 hour lecture; 1 semester hour.

CSCI198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI250. PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM. 3.0 Semester Hrs.
(I, II, S) This course will teach students the skills needed for data collection, analysis, and visualization on a small embedded device (e.g., Raspberry Pi). Students will learn basic Linux, Python, and the programming skills needed to control the hardware and associated sensors. This hands-on course includes a baseline project, four introductory projects (e.g., acoustic, acceleration, magnetic field, optical), and a final Capstone project. The Capstone project will have students create their own application using the techniques learned during the first half of the semester; students will then present their Capstone project through a formal presentation, write-up, and demonstration. We suggest the student take "Introduction to Computer Science" before this course. Co-requisites: MATH213, PHGN200. 3 hours lecture; 3 semester hours.

CSCI260. FORTRAN PROGRAMMING. 2.0 Semester Hrs.
Equivalent with MACS260,
(I) Computer programming in Fortran90/95 with applications to science and engineering. Program design and structure, problem analysis, debugging, program testing. Language skills: arithmetic, input/output, branching and looping, functions, arrays, data types. Introduction to operating systems. Prerequisite: none. 2 hours lecture; 2 semester hours.

CSCI261. PROGRAMMING CONCEPTS. 3.0 Semester Hrs.
Equivalent with MACS261,
(I, II) This course introduces fundamental computer programming concepts using a high-level language and a modern development environment. Programming skills include sequential, selection, and repetition control structures, functions, input and output, primitive data types, basic data structures including arrays and pointers, objects, and classes. Software engineering skills include problem solving, program design, and debugging practices. Prerequisite: none. 3 hours lecture; 3 semester hours.

CSCI262. DATA STRUCTURES. 3.0 Semester Hrs.
Equivalent with MACS262,
(I, II, S) Defining and using data structures such as linked lists, stacks, queues, binary trees, binary heap, hash tables. Introduction to algorithm analysis, with emphasis on sorting and search routines. Language skills: abstract data types, templates and inheritance. Prerequisite: CSCI261 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI274. INTRODUCTION TO THE LINUX OPERATING SYSTEM. 1.0 Semester Hr.
(I,II) Introduction to the Linux Operating System will teach students how to become proficient with using a Linux operating system from the command line. Topics will include: remote login (ssh), file system navigation, file commands, editors, compilation, execution, redirection, output, searching, processes, usage, permissions, compression, parsing, networking, and bash scripting. Prerequisites: CSCI 261. 1 hour lecture; 1 semester hour.

CSCI298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI303. INTRODUCTION TO DATA SCIENCE. 3.0 Semester Hrs.
(II) This course will teach students the core skills needed for gathering, cleaning, organizing, analyzing, interpreting, and visualizing data. Students will learn basic SQL for working with databases, basic Python programming for data manipulation, and the use and application of statistical and machine learning toolkits for data analysis. The course will be primarily focused on applications, with an emphasis on working with real (non-synthetic) datasets. Prerequisites: CSCI101 or CSCI261. 3 hours lecture; 3 semester hours.

CSCI306. SOFTWARE ENGINEERING. 3.0 Semester Hrs.
Equivalent with MACS306,
(I, II) Introduction to software engineering processes and object-oriented design principles. Topics include the Agile development methodology, test-driven development, UML diagrams, use cases and several object-oriented design patterns. Course work emphasizes good programming practices via version control and code reviews. Prerequisite: CSCI262 with grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

CSCI341. COMPUTER ORGANIZATION. 3.0 Semester Hrs.
Equivalent with MACS341,
(I, II) Covers the basic concepts of computer architecture and organization. Topics include machine level instructions and operating system calls used to write programs in assembly language, computer arithmetics, performance, processor design, and pipelining techniques. This course provides insight into the way computers operate at the machine level. Prerequisite: CSCI261. Co-requisites: CSCI262. 3 hours lecture; 3 semester hours.

CSCI358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.
(I, II) This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines and regular languages. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

CSCI370. ADVANCED SOFTWARE ENGINEERING. 6.0 Semester Hrs.
(S) (WI) This capstone course has three primary goals: (1) to enable students to apply their course work knowledge to a challenging applied problem for a real client, (2) to enhance students' verbal and written communication skills, and (3) to provide an introduction to ethical decision making in computer science. Ethics and communication skills are emphasized in a classroom setting. The client work is done in small teams, either on campus or at the client site. Faculty advisors provide guidance related to the software engineering process, which is similar to Scrum. By the end of the course students must have a finished product with appropriate documentation. Prerequisite: CSCI306. 6-week summer session; 6 semester hours.

CSCI398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI400. PRINCIPLES OF PROGRAMMING LANGUAGES. 3.0 Semester Hrs.
Equivalent with MACS400,
(I, II) Study of the principles relating to design, evaluation and implementation of programming languages, including basic compiler techniques and context-free grammars. Students will be exposed to different categories of programming languages, such as functional, imperative, object-oriented and scripting. Best practices for programming will be explored, including effective use of exceptions and threads. The primary languages discussed are: Java, C++, Scheme, and Perl. Prerequisite: CSCI306. 3 hours lecture; 3 semester hours.

CSCI403. DATA BASE MANAGEMENT. 3.0 Semester Hrs.
Equivalent with MACS403,
(I) Design and evaluation of information storage and retrieval systems, including defining and building a database and producing the necessary queries for access to the stored information. Relational database management systems, structured query language, and data storage facilities. Applications of data structures such as lists, inverted lists and trees. System security, maintenance, recovery and definition. Interfacing host languages to database systems and object-relational mapping tools. NoSQL databases and distributed databases. Prerequisite: CSCI262 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

CSCI404. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
Equivalent with MACS404,
(II) General investigation of the Artificial Intelligence field. Several methods used in artificial intelligence such as search strategies, knowledge representation, logic and probabilistic reasoning are developed and applied to practical problems. Fundamental artificial intelligence techniques are presented, including neural networks, genetic algorithms, and fuzzy sets. Selected application areas, such as robotics, natural language processing and games, are discussed. Prerequisite: CSCI262 with a grade of C- or higher, CSCI358 and MATH201. 3 hours lecture; 3 semester hours.

CSCI406. ALGORITHMS. 3.0 Semester Hrs.
Equivalent with MACS406,MATH406,
(I, II) Reasoning about algorithm correctness (proofs, counterexamples). Analysis of algorithms: asymptotic and practical complexity. Review of dictionary data structures (including balanced search trees). Priority queues. Advanced sorting algorithms (heapsort, radix sort). Advanced algorithmic concepts illustrated through sorting (randomized algorithms, lower bounds, divide and conquer). Dynamic programming. Backtracking. Algorithms on unweighted graphs (traversals) and weighted graphs (minimum spanning trees, shortest paths, network flows and bipartite matching); NP-completeness and its consequences. Prerequisite:CSCI262 with a grade of C- or higher, (MATH213 or MATH223 or MATH224), and (MATH300 or MATH358 or CSCI358). 3 hours lecture; 3 semester hours.

CSCI410. ELEMENTS OF COMPUTING SYSTEMS. 3.0 Semester Hrs.
(I, II) This comprehensive course will help students consolidate their understanding of all fundamental computer science concepts. Topics include symbolic communication, Boolean logic, binary systems, logic gates, computer architecture, assembly language, assembler construction, virtual machines, object-oriented programming languages, software engineering, compilers, language design, and operating systems. Using a hardware simulator and a programming language of their choice, students construct an entire modern computer from the ground up, resulting in an intimate understanding of how each component works. Prerequisites: CSCI341 or EENG383. 3 lecture hours, 3 credit hours.

CSCI422. USER INTERFACES. 3.0 Semester Hrs.
Equivalent with MACS422,
(I) User Interface Design is a course for programmers who want to learn how to create more effective software. This objective will be achieved by studying principles and patterns of interaction design, critiquing existing software using criteria presented in the textbooks, and applying criteria to the design and implementation of one larger product. Students will also learn a variety of techniques to guide the software design process, including Cognitive Walkthrough, Talk-aloud and others. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI423. COMPUTER SIMULATION. 3.0 Semester Hrs.
(I) A first course in computer simulation. A project based course emphasizing the rigorous development of simulation applications. Topics will include random number generation, Monte Carlo simulation, discrete event simulation, and the mathematics behind their proper implementation and analysis. To a lesser extent we may discuss, time-step simulations and parallel simulations. The course uses journaling, programming projects and exams for assessment. Prerequisite: CSCI306, and MATH323 or MATH201, and CSCI274. 3 hours lecture; 3 semester hours.

CSCI437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI512,EENG507,EENG512,EGGN512,
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Prerequisites: MATH201 or EENG311, MATH332, CSCI261, Senior level standing. 3 hours lecture; 3 semester hours.

CSCI440. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
Equivalent with MATH440,
(II) This course is designed to introduce the field of parallel computing to all scientists and engineers. The students will be taught how to solve scientific problems using parallel computing technologies. They will be introduced to basic terminologies and concepts of parallel computing, learn how to use MPI to develop parallel programs, and study how to design and analyze parallel algorithms. Prerequisite: CSCI262 with a grade of C- or higher, CSCI341. 3 hours lecture; 3 semester hours.

CSCI441. COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH441,
(I) This class focuses on the basic 3D rendering and modeling techniques. In particular, it covers the graphics pipeline, elements of global illumination, modeling techniques based on polynomial curves and patches, and shader programming using the GPU. Prerequisites: CSCI262 with a grade of C- or higher, MATH332. 3 hours lecture; 3 semester hours.

CSCI442. OPERATING SYSTEMS. 3.0 Semester Hrs.
Equivalent with MACS442,
(I, II) Introduces the essential concepts in the design and implementation of operating systems: what they can do, what they contain, and how they are implemented. Despite rapid OS growth and development, the fundamental concepts learned in this course will endure. We will cover the following high-level OS topics, roughly in this order: computer systems, processes, processor scheduling, memory management, virtual memory, threads, and process/thread synchronization. This course provides insight into the internal structure of operating systems; emphasis is on concepts and techniques that are valid for all computers. Prerequisite: CSCI262 with a grade of C- or higher, CSCI274, CSCI341. 3 hours lecture; 3 semester hours.

CSCI443. ADVANCED PROGRAMMING CONCEPTS USING JAVA. 3.0 Semester Hrs.
Equivalent with MACS443,
(I, II) This course will quickly review programming constructs using the syntax and semantics of the Java programming language. It will compare the constructs of Java with other languages and discuss program design and implementation. Object oriented programming concepts will be reviewed and applications, applets, servlets, graphical user interfaces, threading, exception handling, JDBC, and networking as implemented in Java will be discussed. The basics of the Java Virtual Machine will be presented. Prerequisite: CSCI306. 3 hours lecture; 3 semester hours.

CSCI444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH444,
(II) This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techniques that can be used to develop high-quality computer graphic software. Runtime performance will be evaluated to create optimized real-time graphics applications. In particular, the course will cover global illumination, GPU programming, and virtual and augmented reality. Prerequisites: CSCI441. 3 hours lecture; 3 semester hours.

CSCI445. WEB PROGRAMMING. 3.0 Semester Hrs.
Equivalent with MACS445,
(I) Web Programming is a course for programmers who want to develop web-based applications. It covers basic website design extended by client-side and server-side programming. Students should acquire an understanding of the role and application of web standards to website development. Topics include Cascading Style Sheets (CSS), JavaScript, PHP and database connectivity. At the conclusion of the course students should feel confident that they can design and develop dynamic Web applications on their own. Prerequisites: CSCI262. Co-requisite: CSCI403. 3 hours lecture; 3 semester hours.

CSCI446. WEB APPLICATIONS. 3.0 Semester Hrs.
(II) In Web Applications students will learn how to build effective web-based applications. At the completion of this course, students should know HTTP, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Ajax, and RESTful architectures. Additionally students should have considered a variety of issues related to web application architecture, including but not limited to security, performance, web frameworks and cloud-based deployment environments. Prerequisites: CSCI262. Co-requisites: CSCI403. 3 hours lecture; 3 semester hours.

CSCI447. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with MATH447,
(I) Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on modern visualization techniques applicable to spatial data such as scalar, vector and tensor fields. In particular, the course will cover volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Basic understanding of computer graphics and analysis of algorithms required. Prerequisites: CSCI262 and MATH441. 3 lecture hours, 3 semester hours.

CSCI448. MOBILE APPLICATION DEVELOPMENT. 3.0 Semester Hrs.
(I) This course covers basic and advanced topics in mobile application development. Topics include the mobile application lifecycle, user interface components and layouts, storing persistent data, accessing network resources, using location and sensor APIs including GPS and accelerometer, starting and stopping system services, and threading. This is a project-based course where students will design and develop complete applications. Prerequisite: CSCI306 with a grade of C- or higher. Repeatable: Yes, if taught on a different platform (e.g., Android vs. iPhone) up to 6 hours. 3 hours lecture; 3.0 semester hours.

CSCI455. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.
Equivalent with CSCI555,
(I) An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI358, CSCI406. 3 hours lecture; 3 semester hours.

CSCI470. INTRODUCTION TO MACHINE LEARNING. 3.0 Semester Hrs.
(I) The goal of machine learning is to build computer systems that improve automatically with experience, which has been successfully applied to a variety of application areas, including, for example, gene discovery, financial forecasting, and credit card fraud detection. This introductory course will study both the theoretical properties of machine learning algorithms and their practical applications. Students will have an opportunity to experiment with machine learning techniques and apply them to a selected problem in the context of term projects. Prerequisites: MATH201, MATH332. 3 hours lecture; 3 semester hours.

CSCI471. COMPUTER NETWORKS I. 3.0 Semester Hrs.
(I) This introduction to computer networks covers the fundamentals of computer communications, using TCP/IP standardized protocols as the main case study. The application layer and transport layer of communication protocols will be covered in depth. Detailed topics include application layer protocols (HTTP, FTP, SMTP, and DNS), transport layer protocols (reliable data transfer, connection management, and congestion control), network layer protocols, and link layer protocols. In addition, students will program client/server network applications. Prerequisites: CSCI262, CSCI274. 3 hours lecture; 3 semester hours.

CSCI473. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.
Equivalent with CSCI573,
(II) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH474,
(II) This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography, including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisites: CSCI262, CSCI358, MATH334 or MATH335 or MATH201. 3 hours lecture; 3 semester hours.

CSCI475. INFORMATION SECURITY AND PRIVACY. 3.0 Semester Hrs.
(I) Information Security and Privacy provides a hands-on introduction to the principles and best practices in information and computer security. Lecture topics will include basic components of information security including threat assessment and mitigation, policy development, forensics investigation, and the legal and political dimensions of information security. Prerequisite: CSCI 262 and CSCI 341 (required); CSCI 274 (recommended). 3 hours lecture; 3 semester hours.

CSCI477. ELEMENTS OF GAMES AND GAME DEVELOPMENT. 3.0 Semester Hrs.
(II) This course provides an overview of computer and video game development along with practical game projects designed to introduce the student to the computer entertainment industry. Topics will include the nature of games, the game player, game play, game design, game mechanics, story and character, game worlds, interface and the game development process. Students will be required to develop code both in C++ and with the use of a game engine. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI480. COMPUTER SCIENCE HONORS THESIS. 3.0 Semester Hrs.
(I, II) Prerequisite: CSCI306. 3 hours research; 3 semester hours. Repeatable for credit up to 6 semester hours.

CSCI498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI437,CSCI512,EENG507,EENG512,EGGN512,
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Prerequisites: Undergraduate level knowledge of linear algebra, statistics, and a programming language. 3 hours lecture; 3 semester hours.

CSCI508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with EENG508,
(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

CSCI522. INTRODUCTION TO USABILITY RESEARCH. 3.0 Semester Hrs.
(I) An introduction to the field of Human-Computer Interaction (HCI). Students will review current literature from prominent researchers in HCI and will discuss how the researchers' results may be applied to the students' own software design efforts. Topics include usability testing, ubiquitous computing user experience design, cognitive walkthrough and talk-aloud testing methodologies. Students will work in small teams to develop and evaluate an innovative product or to conduct an extensive usability analysis of an existing product. Project results will be reported in a paper formatted for submission to an appropriate conference (UbiComp, SIGCSE, CHI, etc.). Prerequisite: CSCI 261 or equivalent. 3 hours lecture, 3 semester hours.

CSCI542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542,
(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. Prerequisite: CSCI 262 (or equivalent) and MATH 323 (or MATH 530 or equivalent). 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH544,
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

CSCI546. WEB PROGRAMMING II. 3.0 Semester Hrs.
(I) This course covers methods for creating effective and dynamic web pages, and using those sites as part of a research agenda related to Humanitarian Engineering. Students will review current literature from the International Symposium on Technology and Society (ISTAS), American Society for Engineering Education (ASEE), and other sources to develop a research agenda for the semester. Following a brief survey of web programming languages, including HTML, CSS, JavaScript and Flash, students will design and implement a website to meet their research agenda. The final product will be a research paper which documents the students' efforts and research results. Prerequisite: CSCI 262. 3 hours lecture, 3 semester hours.

CSCI547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with MATH547,
Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

CSCI555. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.
Equivalent with CSCI455,
(II) An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI406 Algorithms. 3 hours lecture; 3 semester hours.

CSCI561. THEORY OF COMPUTATION. 3.0 Semester Hrs.
(I) An introduction to abstract models of computation and computability theory; including finite automata (finite state machines), pushdown automata, and Turing machines. Language models, including formal languages, regular expressions, and grammars. Decidability and undecidability of computational problems. Prerequisite: CSCI/MATH358. 3 hours lecture; 3 semester hours.

CSCI562. APPLIED ALGORITHMS AND DATA STRUCTURES. 3.0 Semester Hrs.
(II) Industry competitiveness in certain areas is often based on the use of better algorithms and data structures. The objective of this class is to survey some interesting application areas and to understand the core algorithms and data structures that support these applications. Application areas could change with each offering of the class, but would include some of the following: VLSI design automation, computational biology, mobile computing, computer security, data compression, web search engines, geographical information systems. Prerequisite: MATH/CSCI406. 3 hours lecture; 3 semester hours.

CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.
The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI341. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED COMPUTING SYSTEMS. 3.0 Semester Hrs.
(II) This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems. Prerequisites: CSCI 442 or equivalent. 3 hours of lecture; 3 semester hours.

CSCI568. DATA MINING. 3.0 Semester Hrs.
Equivalent with MACS568,
(II) This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several applicationspecific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
(I) Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.
Equivalent with MACS572,
(II) This course covers the network layer, data link layer, and physical layer of communication protocols in depth. Detailed topics include routing (unicast, multicast, and broadcast), one hop error detection and correction, and physical topologies. Other topics include state-of-the-art communications protocols for emerging networks (e.g., ad hoc networks and sensor networks). Prerequisite: CSCI 471 or equivalent. 3 hours lecture; 3 semester hours.

CSCI573. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.
Equivalent with CSCI473,
(II) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Students in CSCI 473 will be able to model and analyze human behaviors geared toward human-robot interaction applications. They will also be able to implement a working system using algorithms learnt to solve a given problem in human-centered robotics application. Students in CSCI 573 will get a more in-depth study into the theory of the algorithms. They will be able to compare the different algorithms to select the most appropriate one that can solve a specific problem. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH574,
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI 262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

CSCI575. MACHINE LEARNING. 3.0 Semester Hrs.
Equivalent with MACS575,
(II) The goal of machine learning research is to build computer systems that learn from experience and that adapt to their environments. Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course will focus on the methods that have proven valuable and successful in practical applications. The course will also contrast the various methods, with the aim of explaining the situations in which each is most appropriate. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.

CSCI576. WIRELESS SENSOR SYSTEMS. 3.0 Semester Hrs.
With the advances in computational, communication, and sensing capabilities, large scale sensor-based distributed environments are becoming a reality. Sensor enriched communication and information infrastructures have the potential to revolutionize almost every aspect of human life benefitting application domains such as transportation, medicine, surveillance, security, defense, science and engineering. Such a distributed infrastructure must integrate networking, embedded systems, distributed computing and data management technologies to ensure seamless access to data dispersed across a hierarchy of storage, communication, and processing units, from sensor devices where data originates to large databases where the data generated is stored and/or analyzed. Prerequisite: CSCI406, CSCI446, CSCI471. 3 hours lecture; 3 semester hours.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.
This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

CSCI585. INFORMATION SECURITY PRIVACY. 3.0 Semester Hrs.
(I) This course provides an introduction to the principles and best practices in information security and privacy. Lectures will include basic concepts of information security and privacy, fundamental security design principles, major topics in security and privacy, essential knowledge and skills, risk assessment and mitigation, policy development, and so on. In the classroom, students will also present and discuss a list of recent or classic research papers corresponding to the major topics in security and privacy. Outside of the classroom, students will work on homework assignments, security lab exercises, quizzes, research paper summaries, and a course project. Prerequisites: CSCI262, CSCI341. 3 hours lecture; 3 semester hours.

CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI691. GRADUATE SEMINAR. 1.0 Semester Hr.
Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI692. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with MACS692,MATH692,
Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on underlying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

CSCI698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.
(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

CSM (CSM)

CSM101. FRESHMAN SUCCESS SEMINAR. 0.5 Semester Hrs.
FIRST-YEAR ADVISING AND MENTORING PROGRAM is a "college transition" course, taught in small groups. Emphasis is placed on fostering connectedness to CSM, developing an appreciation of the value of a Mines education, and learning the techniques and University resources that will allow freshmen to develop to their fullest potential at CSM. Course Objectives: Become an integrated member of the CSM community; explore, select and connect with an academic major; and develop as a person and a student. 9 meetings during semester; 0.5 semester hours.

CSM151. SPATIAL VISUALIZATION AND MODELING FOR ENGINEERING AND APPLIED SCIENCE STUDENTS. 1.0 Semester Hr.
(I, II) Research has shown that students with developed spatial visualization skills are more successful in engineering, chemistry, and calculus courses. People can develop these skills over time and with specific training and practice. These skills are not typically taught in high school but are highly valuable in upper-division coursework at Mines. This course aims to heighten a student's ability to mentally rotate and physically manipulate models. Most coursework to be completed in class via applied exercises with individual and group tasks. This course is for degree seeking, undergraduate students (dependent on pre-test score from PSVT:R assessment). 1 hour lecture; 1 semester hour.

CSM201. TRANSFER STUDENT SUCCESS SEMINAR. 0.5 Semester Hrs.
(I, II) Transfer success and mentoring program is a transition course, taught in small groups. Emphasis is placed on fostering connectedness to CSM, discussing strategies in integrating to Mines community, exploring relevant issues associated specifically with the transfer student population, developing an appreciation of the value of a Mines education, and learning the techniques and University resources that will allow transfer students to achieve their goals at CSM. Course Objectives: Become an integrated member of the CSM community; explore campus resource; connect with other transfer students on campus; and develop as a person and a student. For transfer students only. 12 meetings during semester. 1 hour lecture; 0.5 semester hours.

CSM250. ENGINEERING YOUR CAREER PATH. 1.0 Semester Hr.
The purpose of this course is to provide a student with the career planning, job searching tools, work ethics, and life skills that are instrumental to be successful in his or her professional career. Classes and assignments are designed to give the student a head start and constructive feedback in a number of different areas that he or she will have to address through the transition from being a Mines undergraduate student to a summer researcher, intern, full-time employee, and/or graduate student.1 hour lecture, 1 credit hour.

CSM275. CASA BOUNCE BACK PROGRAM. 1.0 Semester Hr.
(I,II) Bounce Back is a course geared towards students who have a goal of raising their GPA. Students in Bounce Back will attend a Saturday kick-off event and weekly small group meetings for the semester. In these sessions, students will be taught strategies they can employ in their daily lives to improve their academic and personal habits. These will range from efficient study techniques, memory recall, focus, efficient study and productivity strategies, time management and many others. Research in student success, how people learn, and human behavior indicates that simply teaching a person many ways to study or manage their time does not always result in long term changes. To complement the academic success strategies we teach, Bounce Back also explores many underlying factors related to success both in and out of the classroom. These relate to topics such as resiliency, mindset, creating purpose and meaning in daily life, and personal. 1.5 hours lecture; 0.5 hours lab; 1 semester hours.

CSM350. STUDIES IN LEADERSHIP. 3.0 Semester Hrs.
(II) The class is an interactive class examining several facets of leadership to help develop leadership abilities and self-awareness. Includes discussion around the Five Principles of Exemplary Leaders, leadership readings, Strengths Finder, ethics and decision making, negotiation and business interactions, and much more. Students take a look at their role as a leader on campus and how to translate their skills in to their career. 2 hours lecture; 3 hours lab; 3 semester hours.

DATA CENTER ENGINEERING (DTCN)

DTCN501. INTRODUCTION TO DATA CENTER ENGINEERING. 3.0 Semester Hrs.
(I, II) This unique course will develop students' foundational knowledge in critical disciplines related to large-scale data center infrastructure design and performance. The course is intended for students with a B.S. in engineering, computer science, or applied and engineering physics who are interested in careers and/or opportunities in data center engineering and management. The course will incorporate real data center examples for introducing analysis of data center design and computing hardware and network requirements; engineering principles for data center power system design, distribution, and control; heat transfer systems for computer system thermal management and building HVAC; and large-scale data file organization, information system architecture, and network and software security. The course will conclude with lectures and an assignment related to sustainability and robustness for data center engineering and design. 3 hours lecture; 3 semester hours.

DTCN502. DATA CENTER INFRASTRUCTURE MANAGEMENT. 3.0 Semester Hrs.
(I, II) This course conveys the basic principles for operating, managing, and optimizing the hardware and software necessary for a large, modern data center. Students will learn how data center components are integrated and managed through software for various applications and in general for security, efficiency, adaptability, robustness, and sustainability. It is intended for graduate students with backgrounds in engineering or computer science. The students will become familiar with best practices in the industry and will demonstrate their knowledge by developing a operations management plan for a specific data center application. 3 hours lecture; 3 semester hours.

DTCN503. DATA CENTER ENGINEERING GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) The Data Center Engineering Seminar will provide students a broad knowledge of current industry and research developments in analysis, design, and operations of Data Center Engineering through once a week discussions and/or seminars from invited guest speakers presenting topics related to data center design, operations, and economics. Students will prepare several short reports on industry developments and/or academic research related to presentations and will deliver a technical presentation and lead a subsequent discussion on an approved topic relevant for the industry. Corequisite: DTCN501. 1 hour seminar; 1 semester hour.

DTCN591. DATA CENTER ENGINEERING DESIGN AND ANALYSIS. 2.0 Semester Hrs.
(I, II) In this graduate-level course, students will participate in a directed team-based project learning through planning, designing, and analyzing a large, modern data center for an industry- or government-relevant application. The course will build on content learned in pre-requisite courses on an Introduction to Data Center Engineering and on Data Center Infrastructure Management. Students will collaborate in multi-disciplinary teams to develop and present the design and analysis of a large, modern data center design for an industry or government application. 2 hours seminar; 2 semester hours.

ECONOMICS AND BUSINESS (EBGN)

EBGN198. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN199. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN201. PRINCIPLES OF ECONOMICS. 3.0 Semester Hrs.
(I,II,S) Introduction to microeconomics and macroeconomics. This course focuses on applying the economic way of thinking and basic tools of economic analysis. Economic effects of public policies. Analysis of markets for goods, services and resources. Tools of cost-benefit analysis. Measures of overall economic activity. Determinants of economic growth. Monetary and fiscal policy. Prerequisites: None. 3 hours lecture; 3 semester hours.

EBGN298. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN301. INTERMEDIATE MICROECONOMICS. 3.0 Semester Hrs.
Equivalent with EBGN411,
(I,II) This course introduces the theoretical and analytical foundations of microeconomics and applies these models to the decisions and interactions of consumers, producers and governments. Develops and applies models of consumer choice and production with a focus on general equilibrium results for competitive markets. Examines the effects of market power and market failures on prices, allocation of resources and social welfare. Prerequisites: EBGN201 and MATH213. 3 hours lecture; 3 semester hours.

EBGN302. INTERMEDIATE MACROECONOMICS. 3.0 Semester Hrs.
Equivalent with EBGN412,
(I,II) Intermediate macroeconomics provides a foundation for analyzing both short-run and long-run economic performance across countries and over time. The course discusses macroeconomic data analysis (including national income and balance of payments accounting), economic fluctuations and the potentially stabilizing roles of monetary, fiscal and exchange rates policies, the role of expectations and intertemporal considerations, and the determinants of long-run growth. The effects of external and internal shocks (such as oil price shocks, resource booms and busts) are analyzed. Prerequisites: EBGN201 and MATH213. 3 hours lecture; 3 semester hours.

EBGN303. ECONOMETRICS. 3.0 Semester Hrs.
Equivalent with EBGN390,
(II) (WI) Introduction to econometrics, including ordinary least-squares and single- equation models; two-stage least-squares and multiple-equation models; specification error, serial correlation, heteroskedasticity, and other problems; distributive-lag models and other extensions, hypothesis testing and forecasting applications. Prerequisites: EBGN201 and MATH201. 3 hours lecture; 3 semester hours.

EBGN304. PERSONAL FINANCE. 3.0 Semester Hrs.
(S) The management of household and personal finances. Overview of financial concepts with special emphasis on their application to issues faced by individuals and households: budget management, taxes, savings, housing and other major acquisitions, borrowing, insurance, investments, meeting retirement goals, and estate planning. Survey of principles and techniques for the management of a household?s assets and liabilities. Study of financial institutions and their relationship to households, along with a discussion of financial instruments commonly held by individuals and families. 3 hours lecture; 3 semester hours.

EBGN305. FINANCIAL ACCOUNTING. 3.0 Semester Hrs.
(I, II) Survey and evaluation of balance sheets and income and expense statements, origin and purpose. Evaluation of depreciation, depletion, and reserve methods for tax and internal management purposes. Cash flow analysis in relation to planning and -decision making. Inventory methods and cost controls related to dynamics of production and processing. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN306. MANAGERIAL ACCOUNTING. 3.0 Semester Hrs.
(II) Introduction to cost concepts and principles of management accounting including cost accounting. The course focuses on activities that create value for customers and owners of a company and demonstrates how to generate cost-accounting information to be used in management decision making. Prerequisite: EBGN201, EBGN305. 3 hours lecture; 3 semester hours.

EBGN310. ENVIRONMENTAL AND RESOURCE ECONOMICS. 3.0 Semester Hrs.
(I) (WI) Application of microeconomic theory to topics in environmental and resource economics. Topics include analysis of pollution control, benefit/cost analysis in decision-making and the associated problems of measuring benefits and costs, non-renewable resource extraction, measures of resource scarcity, renewable resource management, environmental justice, sustainability, and the analysis of environmental regulations and resource policies. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN314. PRINCIPLES OF MANAGEMENT. 3.0 Semester Hrs.
(II) Introduction of underlying principles, fundamentals, and knowledge required of the manager in a complex, modern organization. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN315. THE ECONOMICS OF STRATEGY. 3.0 Semester Hrs.
(I, II, S) An introduction to game theory and industrial organization (IO) principles at a practical and applied level. Topics include economies of scale and scope, the economics of the make-versus-buy decision, market structure and entry, dynamic pricing rivalry, strategic positioning, and the economics of organizational design. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN320. ECONOMICS AND TECHNOLOGY. 3.0 Semester Hrs.
(II) The theoretical, empirical and policy aspects of the economics of technology and technological change. Topics include the economics of research and development, inventions and patenting, the Internet, e-commerce, and incentives for efficient implementation of technology. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN321. ENGINEERING ECONOMICS. 3.0 Semester Hrs.
Equivalent with CHEN421,
(II) Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics on proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, (4) mutually exclusive alternative analysis and service producing alternatives. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN325. OPERATIONS RESEARCH. 3.0 Semester Hrs.
(I) This survey course introduces fundamental operations research techniques in the optimization areas of linear programming, network models (i.e., maximum flow, shortest part, and minimum cost flow), integer programming, and nonlinear programming. Stochastic (probabilistic) topics include queuing theory and simulation. Inventory models are discussed as time permits. The emphasis in this applications course is on problem formulation and obtaining solutions using Excel Software. Prerequisite: Junior Standing, EBGN201, MATH112. 3 hours lecture; 3 semester hours.

EBGN330. ENERGY ECONOMICS. 3.0 Semester Hrs.
Equivalent with ENGY330,
(I) Study of economic theories of optimal resource extraction, market power, market failure, regulation, deregulation, technological change and resource scarcity. Economic tools used to analyze OPEC, energy mergers, natural gas price controls and deregulation, electric utility restructuring, energy taxes, environmental impacts of energy use, government R&D programs, and other energy topics. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN340. ENERGY AND ENVIRONMENTAL POLICY. 3.0 Semester Hrs.
This course considers the intersection of energy and environmental policy from an economic perspective. Policy issues addressed include climate change, renewable resources, externalities of energy use, transportation, and economic development and sustainability. Prerequisites: EBGN201. 3 hours lecture; 3 semester hours.

EBGN342. ECONOMIC DEVELOPMENT. 3.0 Semester Hrs.
(II) (WI) Theories of development and underdevelopment. Sectoral development policies and industrialization. The special problems and opportunities created by an extensive mineral endowment, including the Dutch disease and the resource-curse argument. The effect of value-added processing and export diversification on development. Prerequisite: EBGN201. 3 lecture hours; 3 semester hours. Offered alternate years.

EBGN345. PRINCIPLES OF CORPORATE FINANCE. 3.0 Semester Hrs.
(II) Introduction to corporate finance, financial management, and financial markets. Time value of money and discounted cash flow valuation, risk and returns, interest rates, bond and stock valuation, capital budgeting and financing decisions. Introduction to financial engineering and financial risk management, derivatives, and hedging with derivatives. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN346. INTRODUCTION TO INVESTMENTS. 3.0 Semester Hrs.
(I, II, S) This course is an introduction to the principles of investment in competitive financial markets. The course will provide an overview to: 1) the structure of capital markets, 2) theories and practice of portfolio construction and management, 3) asset pricing theories used to analyze securities, 4) equity and debt securities, and 4) derivative instruments. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN360. INTRODUCTION TO ENTREPRENEURSHIP. 3.0 Semester Hrs.
(II) This course introduces students to the entrepreneurial process, focusing on the concepts, practices, and tools of the entrepreneurial world. This will be accomplished through a combination of readings, cases, speakers, and projects designed to convey the unique environment of entrepreneurship and new ventures. The mastery of concepts covered in this course will lead to an initial evaluation of new venture ideas. In this course students will interact with entrepreneurs, participate in class discussion, and be active participants in the teaching/learning process. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN361. BUSINESS PRINCIPLES FOR ENTREPRENEURS. 3.0 Semester Hrs.
(I) Students will be introduced to each of the functional areas of an entrepreneurial business, including marketing, accounting, finance, operations, human resources management, and business operations. The course is designed to help students appreciate the interrelationship of these business functions and, understand how they operate in an entrepreneurial start-up business. In this course students are expected to participate in class discussion, and be active participants in the teaching/learning process. The class will be highly interactive and your engaged participation and presence will be required. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN398. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN401. ADVANCED TOPICS IN ECONOMICS. 3.0 Semester Hrs.
(I) Application of economic theory to microeconomic and macroeconomic problems. This course will involve both theoretical and empirical modeling. Specific topics will vary by semester depending on faculty and student interest. Topics may include general equilibrium modeling, computational economics, game theory, the economics of information, intertemporal allocations, economic growth, microfoundations of macroeconomic models and policy simulation. Prerequisites: EBGN301, EBGN302 and EBGN303. 3 hours lecture; 3 semester hours.

EBGN403. FIELD SESSION. 3.0 Semester Hrs.
Equivalent with EBGN402,
(S) (WI) An applied course for students majoring in economics. The field session may consist of either participation in a computer simulation or an independent research project under the supervision of a faculty member. In the computer simulation, students work as part of the senior executive team of a company and are responsible for developing and executing a strategy for their company with on-going decisions on everything from new product development, to marketing, to finance and accounting. Prerequisites: EBGN301, EBGN302, EBGN303. 3 semester hours.

EBGN404. ADVANCED TOPICS IN MICROECONOMICS. 3.0 Semester Hrs.
(I) Application of economic theory to microeconomic problems. This course will involve both theoretical and empirical modeling of consumers, producers and markets. Topics may include game theory, risk and uncertainty, the economics of information, intertemporal allocations and general equilibrium modeling. Prerequisites: EBGN301, EBGN302 and EBGN303. 3 hours lecture; 3 semester hours.

EBGN405. ADVANCED TOPICS IN MACROECONOMICS. 3.0 Semester Hrs.
(I) This course is a sequel to Intermediate Macroeconomics. The course will cover (i) modern economic growth theory and empirics; (ii) microfoundations and econometric estimation of macroeconomic relationships, such as consumption, gross fixed investment, inventory behavior and the sustainability of fiscal deficits; and (iii) multi-sectoral models of international trade and finance. Other topics may include real business cycle models, macroeconomic policy simulation, macroeconomic policy efficacy in globally integrated economies, foreign repercussions effects, empirical relationships between interest rates and exchange rates, and interactions between resource industries and the rest of the economy. Prerequisites: EBGN301, ENGN302, EBGN303. 3 hours lecture; 3 semester hours.

EBGN409. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.
(II) Application of mathematical tools to economic problems. Coverage of mathematics needed to read published economic literature and to do graduate study in economics. Topics from differential and integral calculus, matrix algebra, differential equations, and dynamic programming. Applications are taken from mineral, energy, and environmental issues, requiring both analytical and computer solutions using programs such as GAMS and MATHEMATICA. Prerequisites: MATH213, EBGN301, EBGN302. 3 hours lecture; 3 semester hours.

EBGN425. BUSINESS ANALYTICS. 3.0 Semester Hrs.
(I, II, S) With the increasing availability of large volumes of raw business data, the process of converting it into meaningful insights has become critical for organizations to stay competitive. Driven by massive volumes of business data, business analytics has become instrumental in unveiling such managerial practices which guide the decision making process in companies at every operational stage. This course includes various descriptive, predictive and prescriptive business analytics strategies. It provides fundamental skills using quantitative tools to organize, process, and critically interpret business data, as well as key concepts in quantitative decision making to model and solve real-world problems. Prerequisites: EBGN201, MATH112. 3 hours lecture; 3 semester hours.

EBGN430. ADVANCED ENERGY ECONOMICS. 3.0 Semester Hrs.
(I) (WI) Application of economic models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques and applications include market structure, energy efficiency, demand-side management, energy policy and regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: EBGN301, EBGN330. 3 hours lecture; 3 semester hours.

EBGN434. PROPERTY RIGHTS AND NATURAL RESOURCES. 3.0 Semester Hrs.
(II) (WI) When choosing how to allocate our scarce resources, institutions serve as constraints at any given time. Over time, these institutions form and evolve when it appears profitable to do so. This course focuses on the North American story of resource use and draws on economics, law, and history to understand those processes and their implications. The course will provide a framework to understand why certain institutions were adopted and how they now shape our economic decisions today. Prerequisite: EBGN201. 3 hours lecture; 3 semester hours.

EBGN437. REGIONAL ECONOMICS. 3.0 Semester Hrs.
(II) (WI) Analysis of the spatial dimension of economies and economic decisions. Interregional capital and labor mobility. Location decisions of firms and households. Agglomeration economies. Models of regional economic growth. Measuring and forecasting economic impact and regional growth. Local and regional economic development policy. Urban and regional spatial structure. Emphasis on application of tools and techniques of regional analysis. Prerequisite: EBGN301 or EBGN302. 3 hours lecture; 3 semester hours.

EBGN441. INTERNATIONAL ECONOMICS. 3.0 Semester Hrs.
(II) (WI) Theories and determinants of international trade, including static and dynamic comparative advantage and the gains from trade. The history of arguments for and against free trade. The political economy of trade policy in both developing and developed countries. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN443. PUBLIC ECONOMICS. 3.0 Semester Hrs.
(I) (WI) This course covers public-sector economics, including the fundamental institutions and relationships between the government and private decision makers. It covers the fundamental generalequilibrium welfare theorems and their interaction with government policy instruments that affect efficiency and distribution. Normative topics include an intensive study of the causes and consequences of, and policy prescriptions for, market failure due to public goods, or other problems associated with externalities and income distribution. Positive analysis focuses on policy formation in the context of political- economy and public choice theories. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN455. LINEAR PROGRAMMING. 3.0 Semester Hrs.
(I) This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming, an introduction to linear integer programming, and the interior point method are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisites: MATH332 or MATH348 or EBGN409. 3 hours lecture; 3 semester hours.

EBGN459. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.
(II) As a quantitative managerial course, the course will explore how firms can better organize their operations so that they more effectively align their supply with the demand for their products and services. Supply Chain Management (SCM) is concerned with the efficient integration of suppliers, factories, warehouses and retail-stores (or other forms of distribution channels) so that products are provided to customers in the right quantity and at the right time. Topics include managing economies of scale for functional products, managing market- mediation costs for innovative products, make-to order versus make-to-stock systems, quick response strategies, risk pooling strategies, supply-chain contracts and revenue management. Additional "special topics" will also be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN460. BUSINESS PLAN DEVELOPMENT. 3.0 Semester Hrs.
(II) This course leads students through the process of developing a detailed business plan for a start-up company. The creation of a business plan can be challenging, frustrating, fascinating and will lead to a more in-depth understand of how businesses start and operate. Most new ventures are started by teams, with complementary skills and experience sets. In this class, therefore, students will work in teams to develop and write a business plan. This class is also about identifying a new product or service with a viable market and potential to develop into a profitable enterprise by expanding the feasibility study work from EBGN360. This course is the hands-on work of developing a business plan, and as such is intense and demanding. Additionally, this course will integrate previous entrepreneurship, business and economics classes. In this course students are expected to participate in class discussion, and be active participants in the teaching/learning process. The class will be highly interactive and engaged participation and presence will be required. Prerequisites: EBGN360, EBGN361; 3 hours lecture; 3 semester hours.

EBGN461. STOCHASTIC MODELS IN MANAGEMENT SCIENCE. 3.0 Semester Hrs.
(II) As a quantitative managerial course, the course is an introduction to the use of probability models for analyzing risks and economic decisions and doing performance analysis for dynamic systems. The difficulties of making decisions under uncertainty are familiar to everyone. We will learn models that help us quantitatively analyze uncertainty and how to use related software packages for managerial decision-making and to do optimization under uncertainty. Illustrative examples will be drawn from many fields including marketing, finance, production, logistics and distribution, energy and mining. The main focus of the course is to see methodologies that help to quantify the dynamic relationships of sequences of "random" events that evolve over time. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN470. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.
(II) (WI) This course considers the role of markets as they relate to the environment. Topics discussed include environmental policy and economic incentives, market and non-market approaches to pollution regulation, property rights and the environment, the use of benefit/cost analysis in environmental policy decisions, and methods for measuring environmental and nonmarket values. Prerequisite: EBGN301. 3 hours lecture; 3 semester hours.

EBGN474. INVENTING, PATENTING AND LICENSING. 3.0 Semester Hrs.
(S) (WI) This course provides an introduction to the legal framework of inventing and patenting and addresses practical issues facing inventors. The course examines patent law, inventing and patenting in the corporate environment, patent infringement and litigation, licensing, and the economic impact of patents. Methods and resources for market evaluation, searching prior art, documentation and disclosure of invention, and preparing patent applications are presented. Prerequisite: None. 3 hours lecture; 3 semester hours.

EBGN485. BUSINESS STRATEGY. 3.0 Semester Hrs.
(I, II, S) Business strategy is focused on formulating and implementing the major goals of the firm in relation to changing competitive environmental conditions, firm resources, and individuals? motives and values. This course is about the issues and challenges of running a firm in a competitive environment from the perspective of a senior manager. The challenge for senior managers goes well beyond applying an appropriate formula to a problem because to date there are not any universal formulas for successful companies. Rather, senior managers must be able to identify that a problem exists and then to bring resolution, despite partial information. This course requires identifying, analyzing, and solving firm problems with original thinking and execution. A key instructional objective of this course is to help you develop a rigorous approach for addressing complex business problems. Prerequisite: EBGN321 or EBGN345 or EBGN346. 3 hours lecture; 3 semester hours.

EBGN495. ECONOMIC FORECASTING. 3.0 Semester Hrs.
(II) An introduction to the methods employed in business and econometric forecasting. Topics include time series modeling, Box-Jenkins models, vector autoregression, cointegration, exponential smoothing and seasonal adjustments. Covers data collection methods, graphing, model building, model interpretation, and presentation of results. Topics include demand and sales forecasting, the use of anticipations data, leading indicators and scenario analysis, business cycle forecasting, GNP, stock market prices and commodity market prices. Includes discussion of links between economic forecasting and government policy. Prerequisites: EBGN301, EBGN302, EBGN303. 3 hours lecture; 3 semester hours.

EBGN498. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EBGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EBGN504. ECONOMIC EVALUATION AND INVESTMENT DECISION METHODS. 3.0 Semester Hrs.
Time value of money concepts of present worth, future worth, annual worth, rate of return and break-even analysis are applied to after-tax economic analysis of mineral, petroleum and general investments. Related topics emphasize proper handling of (1) inflation and escalation, (2) leverage (borrowed money), (3) risk adjustment of analysis using expected value concepts, and (4) mutually exclusive alternative analysis and service producing alternatives. Case study analysis of a mineral or petroleum investment situation is required. Students may not take EBGN504 for credit if they have completed EBGN321.

EBGN509. MATHEMATICAL ECONOMICS. 3.0 Semester Hrs.
This course reviews and re-enforces the mathematical and computer tools that are necessary to earn a graduate degree in Mineral Economics. It includes topics from differential and integral calculus; probability and statistics; algebra and matrix algebra; difference equations; and linear, mathematical and dynamic programming. It shows how these tools are applied in an economic and business context with applications taken from the mineral and energy industries. It requires both analytical as well as computer solutions. At the end of the course you will be able to appreciate and apply mathematics for better personal, economic and business decision making. Prerequisites: Principles of Microeconomics, and MATH111.

EBGN510. NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.
The threat and theory of resource exhaustion; commodity analysis and the problem of mineral market instability; cartels and the nature of mineral pricing; the environment; government involvement; mineral policy issues; and international mineral trade. This course is designed for entering students in mineral economics. Prerequisite: Principles of Microeconomics.

EBGN511. MICROECONOMICS. 3.0 Semester Hrs.
(I, II, S) This is a graduate course dealing with applied microeconomic theory. The course concentrates on the behavior of individual segments of the economy, the theory of consumer behavior and demand, duality, welfare measures, policy instruments, preferences over time and states of nature, and the fundamentals of game theory. Prerequisites: MATH111, EBGN509. 3 hours lecture; 3 semester hours.

EBGN512. MACROECONOMICS. 3.0 Semester Hrs.
This course will provide an introduction to contemporary macroeconomic concepts and analysis. Macroeconomics is the study of the behavior of the economy as an aggregate. Topics include the equilibrium level of inflation, interest rates, unemployment and the growth in national income. The impact of government fiscal and monetary policy on these variables and the business cycle, with particular attention to the effects on the mineral industry. Prerequisites: Principles of Microeconomics, MATH111.

EBGN515. ECONOMICS AND DECISION MAKING. 3.0 Semester Hrs.
The application of microeconomic theory to business strategy. Understanding the horizontal, vertical, and product boundaries of the modern firm. A framework for analyzing the nature and extent of competition in a firm's dynamic business environment. Developing strategies for creating and sustaining competitive advantage.

EBGN521. MICROECONOMICS OF MINERAL AND ENERGY MARKETS. 3.0 Semester Hrs.
(I) This is a graduate course dealing with applied microeconomic theory. This course concentrates on the behavior of the minerals and energy segment of the economy, the theory of production and cost, the theory of consumer behavior and demand, derived demand, price and output level determination by firms, and the competitive structure of product and input markets. Prerequisites: MATH111, EBGN509. 3 hours lecture; 3 semester hours.

EBGN523. MINERAL AND ENERGY POLICY. 3.0 Semester Hrs.
(II) An analysis of current topics in the news in mineral and energy issues through the lens of economics. Since many of the topics involve government policy, the course provides instruction related to the economic foundations of mineral and energy policy analysis. 3 credit hours.

EBGN525. BUSINESS ANALYTICS. 3.0 Semester Hrs.
(I) This introductory course provides an analytic approach to problems that arise in business. Evaluating alternative courses of action in today's competitive business environment requires the extensive use of data based analytic methods. This course covers deterministic optimization models such as linear programming, non-linear programming, integer programming, and network modeling and an introduction to probability models and linear regression. Applications of the models are covered using spreadsheets. The intent of the course is to enhance analytic modeling abilities and to develop quantitative managerial and spreadsheet skills to support and improve decision making. The models cover applications in the areas of earth, energy, production, logistics, work force scheduling, marketing and finance. 3 hours lecture; 3 semester hours.

EBGN526. STOCHASTIC MODELS IN MANAGEMENT SCIENCE. 3.0 Semester Hrs.
(II) This course introduces the tools of stochastic modeling that are very useful in solving analytical problems in business. We cover methodologies that help to quantify the dynamic relationships of sequences of random events that evolve over time. Topics include static and dynamic Monte-Carlo simulation, discrete and continuous time Markov chains, probabilistic dynamic programming, Markov decision processes, queuing processes and networks, Brownian motion and stochastic control. Applications from a wide range of fields will be introduced including marketing, finance, production, logistics and distribution, energy and service systems. In addition to an intuitive understanding of analytical techniques to model stochastic processes, the course emphasizes how to use related software packages for managerial decision-making. 3 hours lecture; 3 semester hours.

EBGN528. INDUSTRIAL SYSTEMS SIMULATION. 3.0 Semester Hrs.
The course focuses on creating computerized models of real or proposed complex systems for performance evaluation. Simulation provides a cost effective way of pre-testing proposed systems and answering ?what-if? questions before incurring the expense of actual implementations. The course is instructed in the state-of-the-art computer lab (CTLM), where each student is equipped with a personal computer and interacts with the instructor during the lecture. Professional version of a widely used commercial software package, ?Arena?, is used to build models, analyze and interpret the results. Other business analysis and productivity tools that enhance the analysis capabilities of the simulation software are introduced to show how to search for optimal solutions within the simulation models. Both discrete-event and continuous simulation models are covered through extensive use of applications including call centers, various manufacturing operations, production/inventory systems, bulk-material handling and mining, port operations, high-way traffic systems and computer networks. Prerequisites: MATH111, MATH530.

EBGN530. ECONOMICS OF INTERNATIONAL ENERGY MARKETS. 3.0 Semester Hrs.
Application of models to understand markets for oil, gas, coal, electricity, and renewable energy resources. Models, modeling techniques, and issues included are supply and demand, market structure, transportation models, game theory, futures markets, environmental issues, energy policy, energy regulation, input/output models, energy conservation, and dynamic optimization. The emphasis in the course is on the development of appropriate models and their application to current issues in energy markets. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510, EBGN511.

EBGN535. ECONOMICS OF METAL INDUSTRIES AND MARKETS. 3.0 Semester Hrs.
(I, II, S) Metal supply from main product, byproduct, and secondary production. Metal demand and intensity of use analysis. Market organization and price formation. Public policy, comparative advantage, and international metal trade. Metals and economic development in the developing countries and former centrally planned economies. Environmental policy and mining and mineral processing. Students prepare and present a major research paper. Prerequisites: EBGN201, MATH111, EBGN509, and EBGN510. 3 hours lecture; 3 semester hours.

EBGN536. MINERAL POLICIES AND INTERNATIONAL INVESTMENT. 3.0 Semester Hrs.
Identification and evaluation of international mineral investment policies and company responses using economic, business and legal concepts. Assessment of policy issues in light of stakeholder interests and needs. Theoretical issues are introduced and then applied to case studies, policy drafting, and negotiation exercises to assure both conceptual and practical understanding of the issues. Special attention is given to the formation of national policies and corporate decision making concerning fiscal regimes, project financing, environmental protection, land use and local community concerns and the content of exploration and extraction agreements. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510, EBGN511.

EBGN540. ACCOUNTING AND FINANCE. 3.0 Semester Hrs.
(I) Included are the relevant theories associated with capital budgeting, financing decisions, and dividend policy. This course provides an in-depth study of the theory and practice of corporate accounting and financial management including a study of the firm's objectives, investment decisions, long-term financing decisions, and working capital management. Preparation and interpretation of financial statements and the use of this financial information in evaluation and control of the organization. 3 hours lecture; 3 semester hours.

EBGN541. INTERNATIONAL TRADE. 3.0 Semester Hrs.
Theories and evidence on international trade and development. Determinants of static and dynamic comparative advantage. The arguments for and against free trade. Economic development in nonindustrialized countries. Sectoral development policies and industrialization. The special problems and opportunities created by extensive mineral resource endowments. The impact of value-added processing and export diversification on development. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN511.

EBGN542. ECONOMIC DEVELOPMENT. 3.0 Semester Hrs.
Role of energy and minerals in the development process. Sectoral policies and their links with macroeconomic policies. Special attention to issues of revenue stabilization, resource largesse effects, downstream processing, and diversification. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN511, EBGN512.

EBGN546. INVESTMENT AND PORTFOLIO MANAGEMENT. 3.0 Semester Hrs.
This course covers institutional information, valuation theory and empirical analysis of alternative financial investments, including stocks, bonds, mutual funds, ETS, and (to a limited extent) derivative securities. Special attention is paid to the role of commodities (esp. metals and energy products) as an alternative investment class. After an overview of time value of money and arbitrage and their application to the valuation of stocks and bonds, there is extensive treatment of optimal portfolio selection for risk averse investors, mean-variance efficient portfolio theory, index models, and equilibrium theories of asset pricing including the capital asset pricing model (CAPM) and arbitrage pricing theory (APT). Market efficiency is discussed, as are its implications for passive and active approaches to investment management. Investment management functions and policies, and portfolio performance evaluation are also considered. Prerequisites: Principles of Microeconomics, MATH111, MATH530.

EBGN547. FINANCIAL RISK MANAGEMENT. 3.0 Semester Hrs.
Analysis of the sources, causes and effects of risks associated with holding, operating and managing assets by individuals and organizations; evaluation of the need and importance of managing these risks; and discussion of the methods employed and the instruments utilized to achieve risk shifting objectives. The course concentrates on the use of derivative assets in the risk management process. These derivatives include futures, options, swaps, swaptions, caps, collars and floors. Exposure to market and credit risks will be explored and ways of handling them will be reviewed and critiqued through analysis of case studies from the mineral and energy industries. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN505; EBGN545 or EBGN546. Recommended: EBGN509, EBGN511.

EBGN553. PROJECT MANAGEMENT. 3.0 Semester Hrs.
(I, II) Project management has evolved into a business process broadly used in organizations to accomplish goals and objectives through teams. This course covers the essential principles of traditional project management consistent with professional certification requirements (the Project Management Institute?s PMP certification) as well as an introduction to current agile project management methodologies. The traditional project management phases of project initiation, planning, execution, monitoring and control, and project closure are covered including related scheduling, estimating, risk assessment and other analytical tools. Students will gain experience using Microsoft Project. Organizational structure and culture issues are analyzed to understand how they can impact project management success, and the concepts of project portfolios and project programs are applied from the organizational perspective. Agile project management methodologies are introduced, including adaptive and iterative processes, scrum, lean and other agile tools and techniques. By the end of the course, students will understand how traditional and agile project. Prerequisites: Enrollment in the M.S. in Engineering and Technology Management (ETM) Program. 3 hours lecture; 3 semester hours.

EBGN555. LINEAR PROGRAMMING. 3.0 Semester Hrs.
This course addresses the formulation of linear programming models, examines linear programs in two dimensions, covers standard form and other basics essential to understanding the Simplex method, the Simplex method itself, duality theory, complementary slackness conditions, and sensitivity analysis. As time permits, multi-objective programming and stochastic programming are introduced. Applications of linear programming models discussed in this course include, but are not limited to, the areas of manufacturing, finance, energy, mining, transportation and logistics, and the military. Prerequisite: MATH111; MATH332 or EBGN509. 3 hours lecture; 3 semester hours.

EBGN559. SUPPLY CHAIN MANAGEMENT. 3.0 Semester Hrs.
The focus of the course is to show how a firm can achieve better ? supply-demand matching? through the implementation of rigorous mathematical models and various operational/tactical strategies. We look at organizations as entities that must match the supply of what they produce with the demand for their products. A considerable portion of the course is devoted to mathematical models that treat uncertainty in the supply-chain. Topics include managing economies of scale for functional products, managing market-mediation costs for innovative products, make-to order versus make-to-stock systems, quick response strategies, risk pooling strategies, supply-chain contracts and revenue management. Additional ?special topics? may be introduced, such as reverse logistics issues in the supply-chain or contemporary operational and financial hedging strategies, as time permits Prerequisites: MATH111, MATH530.

EBGN560. DECISION ANALYSIS. 3.0 Semester Hrs.
(I) Introduction to the science of decision making and risk theory. Application of decision analysis and utility theory to the analysis of strategic decision problems. Focuses on the application of quantitative methods to business problems characterized by risk and uncertainty. Choice problems such as decisions concerning major capital investments, corporate acquisitions, new product introductions, and choices among alternative technologies are conceptualized and structured using the concepts introduced in this course. 3 hours lecture; 3 semester hours.

EBGN563. MANAGEMENT OF TECHNOLOGY. 3.0 Semester Hrs.
Case studies and reading assignments explore strategies for profiting from technology assets and technological innovation. The roles of strategy, core competencies, product and process development, manufacturing, R&D, marketing, strategic partnerships, alliances, intellectual property, organizational architectures, leadership and politics are explored in the context of technological innovation. The critical role of organizational knowledge and learning in a firm?s ability to leverage technological innovation to gain competitive advantage is explored. The relationships between an innovation, the competencies of the innovating firm, the ease of duplication of the innovation by outsiders, the nature of complementary assets needed to successfully commercialize an innovation and the appropriate strategy for commercializing the innovation are developed. Students explore the role of network effects in commercialization strategies, particularly with respect to standards wars aimed at establishing new dominant designs. Prerequisite: EBGN5043 recommended.

EBGN564. MANAGING NEW PRODUCT DEVELOPMENT. 3.0 Semester Hrs.
Develops interdisciplinary skills required for successful product development in today?s competitive marketplace. Small product development teams step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. Each student brings his or her individual disciplinary perspective to the team effort, and must learn to synthesize that perspective with those of the other students in the group to develop a sound, marketable product. Prerequisite: EBGN563 recommended.

EBGN565. MARKETING FOR TECHNOLOGY-BASED COMPANIES. 3.0 Semester Hrs.
This class explores concepts and practices related to marketing in this unique, fast-paced environment, including the defining characteristics of high-technology industries; different types and patterns of innovations and their marketing implications; the need for (and difficulties in) adopting a customer-orientation; tools used to gather marketing research/intelligence in technology-driven industries; use of strategic alliances and partnerships in marketing technology; adaptations to the "4 P's"; regulatory and ethical considerations in technological arenas. Prerequisite: None.

EBGN566. TECHNOLOGY ENTREPRENEURSHIP. 3.0 Semester Hrs.
Introduces concepts related to starting and expanding a technological-based corporation. Presents ideas such as developing a business and financing plan, role of intellectual property, and the importance of a good R&D program. Prerequisite: None.

EBGN567. BUSINESS LAW AND ETHICS. 3.0 Semester Hrs.
(I) This course incorporates a broad range of legal topics and ethical issues relevant to technology-based organizations, from start-ups to mature Fortune 100 international corporations. The topics encompass numerous aspects of U.S. business law, including but not limited to: the U.S. court system, contracts, e-commerce, managerial ethics, white collar crimes, early stage business formation, intellectual property, product liability, agency law, employment law, mergers and acquisitions, antitrust, and unfair competition law. The course is discussion based, with some lecture, and is 3 semester credit hours. There are no prerequisites required for this course. A significant portion of class time will be applied to exploring and discussing assigned topics through relevant abbreviated court case descriptions, ethics reader assignments and current and recent events in global business. He overall goal of this course is not to make students legal experts but to make them better managers and leaders by equipping them with relevant legal. 3 hours lecture; 3 semester hours.

EBGN568. ADVANCED PROJECT ANALYSIS. 3.0 Semester Hrs.
An advanced course in economic analysis that will look at more complex issues associated with valuing investments and projects. Discussion will focus on development and application of concepts in after-tax environments and look at other criteria and their impact in the decision-making and valuation process. Applications to engineering and technology aspects will be discussed. Effective presentation of results will be an important component of the course. Prerequisite: EBGN504.

EBGN570. ENVIRONMENTAL ECONOMICS. 3.0 Semester Hrs.
The role of markets and other economic considerations in controlling pollution; the effect of environmental policy on resource allocation incentives; the use of benefit/cost analysis in environmental policy decisions and the associated problems with measuring benefits and costs. Prerequisites: Principles of Microeconomics, MATH111, EBGN509, EBGN510.

EBGN571. MARKETING ANALYTICS. 3.0 Semester Hrs.
(II) The purpose of this course is to gain an understanding of how data about customers and markets can be used to support and improve decision making. Using market data to evaluate alternatives and gain insight from past performance is the essence of marketing analytics. The course is focused on the marketing research decisions facing product managers in technology based companies and will appeal to students who want to gain a deeper understanding of such topics as the problems of target market selection, new product introductions, pricing, and customer retention. While the specifics of market analytics can vary across industries and firms, three main commonalities are: (1) defining the decision problem, (2) collection and analysis of high quality market data, and (3) implementing strategy through marketing mix decisions. In this course students will develop an understanding of available marketing analytic methods and the ability to use marketing research information to make strategic and tactical decisions. 3 hours lecture; 3 semester hours.

EBGN572. INTERNATIONAL BUSINESS STRATEGY. 3.0 Semester Hrs.
The purpose of this course is to gain understanding of the complexities presented by managing businesses in an international environment. International business has grown rapidly in recent decades due to technological expansion, liberalization of government policies on trade and resource movements, development of institutions needed to support and facilitate international transactions, and increased global competition. Due to these factors, foreign countries increasingly are a source of both production and sales for domestic companies. Prerequisite: None.

EBGN573. ENTREPRENEURIAL FINANCE. 3.0 Semester Hrs.
Entrepreneurial activity has been a potent source of innovation and job generation in the global economy. In the U.S., the majority of new jobs are generated by new entrepreneurial firms. The financial issues confronting entrepreneurial firms are drastically different from those of established companies. The focus in this course will be on analyzing the unique financial issues which face entrepreneurial firms and to develop a set of skills that has wide applications for such situations. Prerequisite: EBGN505. Corequisite: EBGN545.

EBGN575. ADVANCED MINING AND ENERGY ASSET VALUATION. 3.0 Semester Hrs.
(I) The use of option pricing techniques in mineral and energy asset valuation. Mining and energy valuation standards and guidelines. Differentiation between static decision making, intertemporal decision making, and dynamic decision making under uncertainty. The comparison sales and cost approaches to valuation. Commodity price simulation and price forecasting. Risk-neutral valuation. Prerequisites: EBGN504, EBGN509, EBGN510, EBGN511, EBGN521, EBGN590. 3 hours lecture; 3 semester hours.

EBGN576. MANAGING AND MARKETING NEW PRODUCT DEVELOPMENTS. 3.0 Semester Hrs.
(II) This course provides a scientific approach to developing and marketing new products which are often critical to the success of firms competing in technology based industries. We will start with an overview of core marketing and then develop prototypes of a new product design. We will step through the new product development process in detail, learning about available tools and techniques to execute each process step along the way. New product prototypes will be used to gather data from prospective target markets and assess the viability of the design in the marketplace. 3 hours lecture; 3 semester hours.

EBGN580. EXPLORATION ECONOMICS. 3.0 Semester Hrs.
Exploration planning and decision making for oil and gas, and metallic minerals. Risk analysis. Historical trends in exploration activity and productivity. Prerequisites: Principles of Microeconomics, EBGN510. Offered when student demand is sufficient.

EBGN585. ENGINEERING AND TECHNOLOGY MANAGEMENT CAPSTONE. 3.0 Semester Hrs.
This course represents the culmination of the ETM Program. This course is about the strategic management process ? how strategies are developed and imple mented in organizations. It examines senior management?s role in formulating strategy and the role that all an organization?s managers play in implementing a well thought out strategy. Among the topics discussed in this course are (1) how different industry conditions support different types of strategies; (2) how industry conditions change and the implication of those changes for strategic management; and (3) how organizations develop and maintain capabilities that lead to sustained competitive advantage. This course consists of learning fundamental concepts associated with strategic management process and competing in a web-based strategic management simulation to support the knowledge that you have developed. Prerequisites: MATH530, EBGN504.

EBGN590. ECONOMETRICS I. 3.0 Semester Hrs.
(II) This course covers the statistical methods used by economists to estimate economic relationships and empirically test economic theories. Topics covered include hypothesis testing, ordinary least squares, specification error, serial correlations, heteroskedasticity, qualitative and limited dependent variables, time series analysis and panel data. Prerequisites: MATH111, MATH530, EBGN509. 3 hours lecture and discussion; 3 semester hours.

EBGN594. TIME-SERIES ECONOMETRICS. 3.0 Semester Hrs.
(II) This is a course in applied time-series econometrics. It covers contemporary approaches for interpreting and analyzing time-series economic data. Hypothesis testing and forecasting both receive attention. Topics include stochastic difference equations, applied forecasting, stationary univariate models, models with constant and time-varying variance, deterministic and stochastic trend models and associated unit root and structural break tests, as well as single-equation and multiple-equation time-series models that include error-correction techniques and cointegration tests. 3 hours lecture; 3 semester hours.

EBGN598. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN610. ADVANCED NATURAL RESOURCE ECONOMICS. 3.0 Semester Hrs.
Optimal resource use in a dynamic context using mathematical programming, optimal control theory and game theory. Constrained optimization techniques are used to evaluate the impact of capital constraints, exploration activity and environmental regulations. Offered when student demand is sufficient. Prerequisites: Principles of Microeconomics, MATH111, MATH5301, EBGN509, EBGN510, EBGN511.

EBGN611. ADVANCED MICROECONOMICS. 3.0 Semester Hrs.
A second graduate course in microeconomics, emphasizing state-of-the-art theoretical and mathematical developments. Topics include consumer theory, production theory and the use of game theoretic and dynamic optimization tools. Prerequisites: Principles of Microeconomics, MATH111, MATH5301, EBGN509, EBGN511.

EBGN632. PRIMARY FUELS. 3.0 Semester Hrs.
(II) Application of models to understand markets for oil, gas, coal exploration and extraction. Empirical, theoretical and quantitative models and modeling techniques are stressed. The issues included are identification of cause and effect, market structure, game theory, futures markets, environmental issues, energy policy, energy regulation. The emphasis in the course is on the development of appropriate models and their application to current issues in primary fuel/upstream markets. Prerequisites: EBGN590. 3 hours lecture; 3 semester hours.

EBGN645. COMPUTATIONAL ECONOMICS. 3.0 Semester Hrs.
(II) This course is about learning the skills required to construct and manipulate numerical models as an instrument of economic research. In the first part of the course, students will learn about basic classes of optimization problems as ways to operationalize models of equilibrium behavior from economics and how to formulate and solve these problems on the computer. In the second part of the course, students will focus on the techniques used specifically in computable general equilibrium (CGE) analysis and developing applications of CGE models to topics in energy, environmental and natural resource economics. Prerequisites: MATH111, MATH530, Principles of Microeconomics, EBGN509, EBGN511. 3 hours lecture; 3 semester hours.

EBGN655. ADVANCED LINEAR PROGRAMMING. 3.0 Semester Hrs.
Equivalent with EBGN650,
As an advanced course in optimization, this course will expand upon topics in linear programming. Specific topics to be covered include advanced formulation, column generation, interior point method, stochastic optimization, and numerical stability in linear programming. Applications of state-of-the-art hardware and software will emphasize solving real-world problems in areas such as mining, energy, transportation and the military. Prerequisites: EBGN555. 3 hours lecture; 3 semester hours.

EBGN690. ECONOMETRICS II. 3.0 Semester Hrs.
A second course in econometrics. Compared to EBGN590, this course provides a more theoretical and mathematical understanding of econometrics. Matrix algebra is used and model construction and hypothesis testing are emphasized rather than forecasting. Prerequisites: Principles of Microeconomics, MATH111, MATH530, EBGN509, EBGN590. Recommended: EBGN511.

EBGN695. RESEARCH METHODOLOGY. 3.0 Semester Hrs.
Lectures provide an overview of methods used in economic research relating to EPP and QBA/OR dissertations in Mineral Economics and information on how to carry out research and present research results. Students will be required to write and present a research paper that will be submitted for publication. It is expected that this paper will lead to a Ph.D. dissertation proposal. It is a good idea for students to start thinking about potential dissertation topic areas as they study for their qualifier. This course is also recommended for students writing Master? s thesis or who want guidance in doing independent research relating to the economics and business aspects of energy, minerals and related environmental and technological topics. Prerequisites: MATH530, EBGN509, EBGN510, EBGN511, EBGN590.

EBGN698. SPECIAL TOPICS IN ECONOMICS AND BUSINESS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EBGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EBGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

ELECTRICAL ENGINEERING (EENG)

EENG198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG281. INTRODUCTION TO ELECTRICAL CIRCUITS, ELECTRONICS AND POWER. 3.0 Semester Hrs.
Equivalent with DCGN381,EGGN281,EGGN381,
(I, II) This course provides an engineering science analysis of electrical circuits. DC and single-phase AC networks are presented. Transient analysis of RC, RL, and RLC circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and single-phase AC circuit analysis, current and charge relationships. Ohm?s Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff?s Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and ideal transformers. The course features PSPICE, a commercial circuit analysis software package. May not also receive credit for EENG282. Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

EENG282. ELECTRICAL CIRCUITS. 4.0 Semester Hrs.
(I,II) This course provides an engineering science analysis of electrical circuits. DC and AC (single-phase and three-phase) networks are presented. Transient analysis of RC and RL circuits is studied as is the analysis of circuits in sinusoidal steady-state using phasor concepts. The following topics are included: DC and AC circuit analysis, current and charge relationships. Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thevenin and Norton equivalent circuits, superposition and source transformation, power and energy, maximum power transfer, first order transient response, algebra of complex numbers, phasor representation, time domain and frequency domain concepts, and steady-state analysis of single-phase and three-phase ac power circuits. May not also receive credit for EENG281. Prerequisites: PHGN200. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG284. DIGITAL LOGIC. 4.0 Semester Hrs.
Equivalent with EGGN284,EGGN384,
(I, II) Fundamentals of digital logic design. Covers combinational and sequential logic circuits, programmable logic devices, hardware description languages, and computer-aided design (CAD) tools. Laboratory component introduces simulation and synthesis software and hands-on hardware design. Prerequisites: CSCI261. Co-requisites: EENG282 or EENG281 or PHGN215. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG298. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG307. INTRODUCTION TO FEEDBACK CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN307,EGGN407,
(I, II) System modeling through an energy flow approach is presented, with examples from linear electrical, mechanical, fluid and/or thermal systems. Analysis of system response in both the time domain and frequency domain is discussed in detail. Feedback control design techniques, including PID, are analyzed using both analytical and computational methods. Prerequisites: EENG281 or EENG282 or PHGN215, and MATH225. 3 hours lecture; 3 semester hours.

EENG310. INFORMATION SYSTEMS SCIENCE I. 4.0 Semester Hrs.
Equivalent with EENG388,EGGN388,
(I, II) The interpretation, representation and analysis of time-varying phenomena as signals which convey information and noise; applications are drawn from filtering, audio and image processing, and communications. Topics include convolution, Fourier series and transforms, sampling and discrete-time processing of continuous-time signals, modulation, and z-transforms. Prerequisites: (EENG281 or EENG282 or PHGN215) and MATH225. 3 hours lecture; 1 hour recitation, 4 semester hours.

EENG311. INFORMATION SYSTEMS SCIENCE II. 3.0 Semester Hrs.
(I,II) This course covers signals and noise in electrical systems. Topics covered include information theory, signal to noise ratio, random variables, probability density functions, statistics, noise, matched filters, coding and entropy, power spectral density, and bit error rate. Applications are taken from radar, communications systems, and signal processing. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

EENG334. ENGINEERING FIELD SESSION, ELECTRICAL. 3.0 Semester Hrs.
Equivalent with EGGN334,
(S) Experience in the engineering design process involving analysis, design, and simulation. Students use engineering, mathematics and computers to model, analyze, design and evaluate system performance. Teamwork emphasized. Prerequisites: EENG284 (C- or better), EENG385 and EENG389. Three weeks in summer session; 3 semester hours.

EENG340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
Equivalent with EGGN340,EGGN340E,
(I,II,S) Supervised, full-time engineering related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Department Head prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisites: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EENG340, Cooperative Education, may be used as free elective credit hours if, in the judgment of the Department Head, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives requires the student to submit a Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements form obtained from the Career Center to the Department Head.

EENG383. MICROCOMPUTER ARCHITECTURE AND INTERFACING. 4.0 Semester Hrs.
Equivalent with EGGN383,EGGN482,
(I, II) Microprocessor and microcontroller architecture focusing on hardware structures and elementary machine and assembly language programming skills essential for use of microprocessors in data acquisition, control, and instrumentation systems. Analog and digital signal conditioning, communication, and processing. A/D and D/A converters for microprocessors. RS232 and other communication standards. Laboratory study and evaluation of microcomputer system; design and implementation of interfacing projects. Prerequisites: (EENG281 or EENG282 or PHGN215) and EENG284 or PHGN317. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG385. ELECTRONIC DEVICES AND CIRCUITS. 4.0 Semester Hrs.
Equivalent with EGGN385,
(I, II) Semiconductor materials and characteristics, junction diode operation, bipolar junction transistors, field effect transistors, biasing techniques, four layer devices, amplifier and power supply design, laboratory study of semiconductor circuit characteristics. Prerequisite: EENG307. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG386. FUNDAMENTALS OF ENGINEERING ELECTROMAGNETICS. 3.0 Semester Hrs.
Equivalent with EGGN386,
(I, II) This course provides an introduction to electromagnetic theory as applied to electrical engineering problems in wireless communications, transmission lines, and high-frequency circuit design. The theory and applications are based on Maxwell's equations, which describe the electric and magnetic force-fields, the interplay between them, and how they transport energy. Matlab and PSPICE will be used in homework assignments, to perform simulations of electromagnetic interference, electromagnetic energy propagation along transmission lines on printed circuit boards, and antenna radiation patterns. Prerequisites: EENG281 (C- or better) or EENG282 (C- or better), and MATH225. 3 hours lecture; 3 semester hours.

EENG389. FUNDAMENTALS OF ELECTRIC MACHINERY. 4.0 Semester Hrs.
Equivalent with EGGN389,
(I, II) This course provides an engineering analysis of electrical machines. The following topics are included: review of three-phase AC circuit analysis, magnetic circuit concepts and materials, transformer analysis and operation, modelling, steady-state analysis of rotating machines, synchronous and poly-phase induction motors, and DC machines and laboratory study of external characteristics of machines and transformers. Prerequisite: EENG281 (C- or better) or EENG282 (C- or better). 3 hours lecture, 3 hours lab; 4 semester hours.

EENG390. ENERGY, ELECTRICITY, RENEWABLE ENERGY, AND ELECTRIC POWER GRID. 3.0 Semester Hrs.
(I) (WI) Fundamentals and primary sources of energy; Energy conversion; Comprehensive energy picture in USA and the world; Generation of electric power today; Understanding of the electric power grid and how it works; Renewable energy resources and distributed generation; Wind and PV power generation; Future trend in electricity delivery; Energy sustainability. Prerequisites: EENG281 or EENG282 or PHGN215. 3 hours lecture; 3 semester hours.

EENG395. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I, II) Individual research project for freshman, sophomores or juniors under direction of a member of the departmental faculty. Written report required for credit. Seniors should take EENG495 instead of EENG395. Repeatable for credit. Variable credit; 1 to 3 semester hours.

EENG398. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG411. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN481,
(II) This course introduces the mathematical and engineering aspects of digital signal processing (DSP). An emphasis is placed on the various possible representations for discrete-time signals and systems (in the time, z-, and frequency domains) and how those representations can facilitate the identification of signal properties, the design of digital filters, and the sampling of continuous-time signals. Advanced topics include sigma-delta conversion techniques, multi-rate signal processing, and spectral analysis. The course will be useful to all students who are concerned with information bearing signals and signal processing in a wide variety of application settings, including sensing, instrumentation, control, communications, signal interpretation and diagnostics, and imaging. Prerequisite: EENG310. 3 hours lecture; 3 semester hours.

EENG413. ANALOG AND DIGITAL COMMUNICATION SYSTEMS. 4.0 Semester Hrs.
Equivalent with EGGN483,
(II) Signal classification; Fourier transform; filtering; sampling; signal representation; modulation; demodulation; applications to broadcast, data transmission, and instrumentation. Prerequisite: EENG310. 3 hours lecture; 3 hours lab; 4 semester hours.

EENG417. MODERN CONTROL DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN417,
(I) Control system design with an emphasis on observer-based methods, from initial open-loop experiments to final implementation. The course begins with an overview of feedback control design technique from the frequency domain perspective, including sensitivity and fundamental limitations. State space realization theory is introduced, and system identification methods for parameter estimation are introduced. Computerbased methods for control system design are presented. Prerequisite: EENG307. 3 lecture hours, 3 semester hours.

EENG421. SEMICONDUCTOR DEVICE PHYSICS AND DESIGN. 3.0 Semester Hrs.
(I) This course will explore the field of semiconductors and the technological breakthroughs which they have enabled. We will begin by investigating the physics of semiconductor materials, including a brief foray into quantum mechanics. Then, we will focus on understanding pn junctions in great detail, as this device will lead us to many others (bipolar transistors, LEDs, solar cells). We will explore these topics through a range of sources (textbooks, scientific literature, patents) and discuss the effects they have had on Western society. As time allows, we will conclude with topics of interest to the students (possibilities include quantum devices, MOSFETs, lasers, and integrated circuit fabrication techniques). Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

EENG423. INTRODUCTION TO VLSI DESIGN. 3.0 Semester Hrs.
(II) This is an introductory course that will cover basic theories and techniques of digital VLSI (Very Large Scale Integrated Circuits) design and CMOS technology. The objective of this course is to understand the theory and design of digital systems at the transistor level. The course will cover MOS transistor theory, CMOS processing technology, techniques to design fast digital circuits, techniques to design power efficient circuits, standard CMOS fabrications processes, CMOS design rules, and static and dynamic logic structures. Prerequisites: EENG281 (C- or better) or EENG282 (C- or better), and EENG284 (C- or better). 3 hours lecture; 3 semester hours.

EENG425. INTRODUCTION TO ANTENNAS. 3.0 Semester Hrs.
(II) This course provides an introduction to antennas and antenna arrays. Theoretical analysis and use of computer programs for antenna analysis and design will be presented. Experimental tests and demonstrations will also be conducted to complement the theoretical analysis. Students are expected to use MATLAB to model antennas and their performance. Prerequisites: EENG386.

EENG427. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
(I, II, S) This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. Prerequisites: EENG311 or MATH201 and EENG310. 3 hours lecture; 3 semester hours.

EENG428. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.
(I) This course provides the basic formulation and numerical solution for static electric problems based on Laplace, Poisson and wave equations and for full wave electromagnetic problems based on Maxwell's equations. Variation principles methods, including the finite-element method and method of moments will be introduced. Field to circuit conversion will be discussed via the transmission line method. Numerical approximations based on the finite difference and finite difference frequency domain techniques will also be developed for solving practical problems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG429. ACTIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(II) This course introduces the basics of active radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are RF and microwave circuit components, resonant circuits, matching networks, noise in active circuits, switches, RF and microwave transistors and amplifiers. Additionally, mixers, oscillators, transceiver architectures, RF and monolithic microwave integrated circuits (RFICs and MMICs) will be introduced. Moreover, students will learn how to model active devices using professional CAD software, how to fabricate printed active microwave devices, how a vector network analyzer (VNA) operates, and how to measure active RF and microwave devices using VNAs. Prerequisites: EENG385. 3 hours lecture; 3 semester hours.

EENG430. PASSIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(I) This course introduces the basics of passive radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are microwave transmission lines and waveguides, microwave network theory, microwave resonators, power dividers, directional couplers, hybrids, RF/microwave filters, and phase shifters. Students will also learn how to design and analyze passive microwave devices using professional CAD software. Moreover, students will learn how to fabricate printed passive microwave devices and test them using a vector network analyzer. Prerequisites: EENG386. 3 hours lecture; 3 semester hours.

EENG437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Prerequisites: MATH201 or EENG311, MATH332, CSCI261, Senior level standing. 3 hours lecture; 3 semester hours.

EENG450. SYSTEMS EXPLORATION AND ENGINEERING DESIGN LAB. 1.0 Semester Hr.
(I, II) This laboratory is a semester-long design and build activity centered around a challenge problem that varies from year to year. Solving this problem requires the design and prototyping of a complex system and utilizes concepts from multiple electrical engineering courses. Students work in intra-disciplinary teams, with students focusing on either embedded systems or control systems. Prerequisites: EENG383 and EENG307. 3 hours lab; 1 semester hour.

EENG470. INTRODUCTION TO HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Equivalent with EGGN485,
(I) Power electronics are used in a broad range of applications from control of power flow on major transmission lines to control of motor speeds in industrial facilities and electric vehicles, to computer power supplies. This course introduces the basic principles of analysis and design of circuits utilizing power electronics, including AC/DC, AC/AC, DC/DC, and DC/AC conversions in their many configurations. Prerequisite: EENG282. 3 hours lecture; 3 semester hours.

EENG472. PRACTICAL DESIGN OF SMALL RENEWABLE ENERGY SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN486,
(Taught on Demand) This course provides the fundamentals to understand and analyze renewable energy powered electric circuits. It covers practical topics related to the design of alternative energy based systems. It is assumed the students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, electronics, and fundamentals of electric power systems. One of the main objectives of this course is to focus on the interdisciplinary aspects of integration of the alternative sources of energy, including hydropower, wind power, photovoltaic, and energy storage for those systems. Power electronic systems will be discussed and how those electronic systems can be used for stand-alone and grid-connected electrical energy applications. Prerequisite: EENG382. 3 hours lecture; 3 semester hours.

EENG480. POWER SYSTEMS ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN484,
(I) 3-phase power systems, per-unit calculations, modeling and equivalent circuits of major components, voltage drop, fault calculations, symmetrical components and unsymmetrical faults, system grounding, power-flow, selection of major equipment, design of electric power distribution systems. Prerequisite: EENG389. 3 hours lecture; 3 semester hours.

EENG481. ANALYSIS AND DESIGN OF ADVANCED ENERGY SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN487,
(II) The course investigates the design, operation and analysis of complex interconnected electric power grids, the basis of our electric power infrastructure. Evaluating the system operation, planning for the future expansion under deregulation and restructuring, ensuring system reliability, maintaining security, and developing systems that are safe to operate has become increasingly more difficult. Because of the complexity of the problems encountered, analysis and design procedures rely on the use of sophisticated power system simulation computer programs. The course features some commonly used commercial software packages. Prerequisites: EENG480. 2 Lecture Hours, 3 Laboratory Hours, 3 Semester Hours.

EENG486. ELECTROMAGNETIC FIELDS AND WAVES. 3.0 Semester Hrs.
(I) This course provides an introduction to electromagnetic fields and waves and their applications in antennas, radar, high-frequency electronics, and microwave devices. The time-varying form of electromagnetic fields and the use of sinusoidal time sources to create time-harmonic electromagnetic fields will be covered first, followed by coverage of plane electromagnetic waves formulation and reflection and transmission from different surfaces. Finally, the application of guided electromagnetic waves will be covered through the study of transmission lines, waveguides, and their applications in microwave systems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG489. COMPUTATIONAL METHODS IN ENERGY SYSTEMS AND POWER ELECTRONICS. 3.0 Semester Hrs.
(II) The course presents a unified approach for understanding and applying computational methods, computer-aided analysis and design of electric power systems. Applications will range from power electronics to power systems, power quality, and renewable energy. Focus will be on how these seemingly diverse applications all fit within the smart-grid paradigm. This course builds on background knowledge of electric circuits, control of dc/dc converters and inverters, energy conversion and power electronics by preparing students in applying the computational methods for multi-domain simulation of energy systems and power electronics engineering problems. Prerequisites: EENG282 or EENG382. 1 hour lecture, 2 lab hours, 3 semester hours.

EENG495. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(I, II) Individual research project under direction of a member of the departmental faculty. Written report required for credit. Prerequisites: senior-level standing based on credit hours. Variable credit; 1 to 3 semester hours. Repeatable for credit.

EENG498. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EENG504. ENGINEERING SYSTEMS SEMINAR - ELECTRICAL. 1.0 Semester Hr.
Equivalent with EGGN504E,
(I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today?s competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Engineering graduate program. Prerequisite: Graduate standing. 1 hour seminar, 1 semester hour. Repeatable; maximum 1 hour granted toward degree requirements.

EENG507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI507,CSCI512,EENG512,EGGN512,
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Prerequisites: Undergraduate level knowledge of linear algebra, statistics, and a programming language. 3 hours lecture; 3 semester hours.

EENG508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCI508,
(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

EENG509. SPARSE SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN509,
(II) This course presents a mathematical tour of sparse signal representations and their applications in modern signal processing. The classical Fourier transform and traditional digital signal processing techniques are extended to enable various types of computational harmonic analysis. Topics covered include time-frequency and wavelet analysis, filter banks, nonlinear approximation of functions, compression, signal restoration, and compressive sensing. Prerequisites: EENG411 and EENG515. 3 hours lecture; 3 semester hours.

EENG511. CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS. 3.0 Semester Hrs.
(II) The course focuses on recognizing and solving convex optimization problems that arise in applications in various engineering fields. Covered topics include basic convex analysis, conic programming, duality theory, unconstrained optimization, and constrained optimization. The application part covers problems in signal processing, power and energy, machine learning, control and mechanical engineering, and other fields, with an emphasis on modeling and solving these problems using the CVX package. Offered Spring semester of even years. Prerequisites: EENG311 and EENG511. 3 hours lecture; 3 semester hours.

EENG515. MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN515,
(I) An introduction to mathematical methods for modern signal processing using vector space methods. Topics include signal representation in Hilbert and Banach spaces; linear operators and the geometry of linear equations; LU, Cholesky, QR, eigen- and singular value decompositions. Applications to signal processing and linear systems are included throughout, such as Fourier analysis, wavelets, adaptive filtering, signal detection, and feedback control.

EENG517. THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN517,
(II) This course will introduce and study the theory and design of multivariable and nonlinear control systems. Students will learn to design multivariable controllers that are both optimal and robust, using tools such as state space and transfer matrix models, nonlinear analysis, optimal estimator and controller design, and multi-loop controller synthesis. Spring semester of even years. Prerequisites: EENG417. 3 hours lecture; 3 semester hours.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.
Equivalent with EGGN519,
(II) Estimation theory considers the extraction of useful information from raw sensor measurements in the presence of signal uncertainty. Common applications include navigation, localization and mapping, but applications can be found in all fields where measurements are used. Mathematic descriptions of random signals and the response of linear systems are presented. The discrete-time Kalman Filter is introduced, and conditions for optimality are described. Implementation issues, performance prediction, and filter divergence are discussed. Adaptive estimation and nonlinear estimation are also covered. Contemporary applications will be utilized throughout the course. Offered spring semester of odd years. Prerequisites: EENG515 and undergraduate knowledge of probability theory. 3 hours lecture; 3 semester hours.

EENG525. ANTENNAS. 3.0 Semester Hrs.
(I, II) This course provides an in depth introduction to the analysis and synthesis of antennas and antenna arrays. Students are expected to use MATLAB to model antennas and their performance. An extensive final project that involves experimental or computer demonstrations is required. EENG525 has more depth and required work than EENG425. EENG525 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on antenna and direction finding projects. Prerequisites: EGGN386 or GPGN302 or PHGN384. 3 hours lecture; 3 semester hours.

EENG526. ADVANCED ELECTROMAGNETICS. 3.0 Semester Hrs.
(II) In this course the fundamental theorems of electromagnetics are developed rigorously. Wave solutions are developed in Cartesian, cylindrical, and spherical coordinate systems for bounded and unbounded regions. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG527. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
Equivalent with EENG513,EGGN513,
(I, II) This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. EENG527 has more depth and required work than EENG427. EENG527 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on final project. Prerequisites: EENG386, EENG311, and EENG388. 3 hours lecture, 3 semester hours.

EENG528. COMPUTATIONAL ELECTROMAGNETICS. 3.0 Semester Hrs.
(I) This course provides the basic formulation and numerical solution for static electric problems based on Laplace, Poisson and wave equations and for full wave electromagnetic problems based on Maxwell? s equations. Variation principles methods, including the finite-element method and method of moments will be introduced. Field to circuit conversion will be discussed via the transmission line method. Numerical approximations based on the finite difference and finite difference frequency domain techniques will also be developed for solving practical problems. Prerequisite: EENG386. 3 hours lecture; 3 semester hours.

EENG529. ACTIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(II) This course introduces the basics of active radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are RF and microwave circuit components, resonant circuits, matching networks, noise in active circuits, switches, RF and microwave transistors and amplifiers. Additionally, mixers, oscillators, transceiver architectures, RF and monolithic microwave integrated circuits (RFICs and MMICs) will be introduced. Moreover, students will learn how to model active devices using professional CAD software, how to fabricate printed active microwave devices, how a vector network analyzer (VNA) operates, and how to measure active RF and microwave devices using VNAs. Prerequisites: EEBG385. 3 hours lecture; 3 semester hours.

EENG530. PASSIVE RF & MICROWAVE DEVICES. 3.0 Semester Hrs.
(I) This course introduces the basics of passive radio-frequency (RF) and microwave circuits and devices which are the building blocks of modern communication and radar systems. The topics that will be studied are microwave transmission lines and waveguides, microwave network theory, microwave resonators, power dividers, directional couplers, hybrids, RF/microwave filters, and phase shifters. Students will also learn how to design and analyze passive microwave devices using professional CAD software. Moreover, students will learn how to fabricate printed passive microwave devices and test them using a vector network analyzer. Prerequisites: EENG386. 3 hours lecture; 3 semester hours.

EENG570. ADVANCED HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Equivalent with EGGN585,
(I) Basic principles of analysis and design of circuits utilizing high power electronics. AC/DC, DC/AC, AC/AC, and DC/DC conversion techniques. Laboratory project comprising simulation and construction of a power electronics circuit. Prerequisites: EENG385; EENG389 or equivalent. 3 hours lecture; 3 semester hours. Fall semester even years.

EENG571. MODERN ADJUSTABLE SPEED ELECTRIC DRIVES. 3.0 Semester Hrs.
Equivalent with EGGN581,
An introduction to electric drive systems for advanced applications. The course introduces the treatment of vector control of induction and synchronous motor drives using the concepts of general flux orientation and the feedforward (indirect) and feedback (direct) voltage and current vector control. AC models in space vector complex algebra are also developed. Other types of drives are also covered, such as reluctance, stepper-motor and switched-reluctance drives. Digital computer simulations are used to evaluate such implementations. Pre-requisite: Familiarity with power electronics and power systems, such as covered in EENG480 and EENG470. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG572. RENEWABLE ENERGY AND DISTRIBUTED GENERATION. 3.0 Semester Hrs.
Equivalent with EGGN582,
A comprehensive electrical engineering approach on the integration of alternative sources of energy. One of the main objectives of this course is to focus on the inter-disciplinary aspects of integration of the alternative sources of energy which will include most common and also promising types of alternative primary energy: hydropower, wind power, photovoltaic, fuel cells and energy storage with the integration to the electric grid. Pre-requisite: It is assumed that students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, power electronics, direct energy conversion, and fundamentals of electric power systems such as covered in basic engineering courses plus EENG480 and EENG470. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG573. ELECTRIC POWER QUALITY. 3.0 Semester Hrs.
Equivalent with EGGN580,
(II) Electric power quality (PQ) deals with problems exhibited by voltage, current and frequency that typically impact end-users (customers) of an electric power system. This course is designed to familiarize the concepts of voltage sags, harmonics, momentary disruptions, and waveform distortions arising from various sources in the system. A theoretical and mathematical basis for various indices, standards, models, analyses techniques, and good design procedures will be presented. Additionally, sources of power quality problems and some remedies for improvement will be discussed. The course bridges topics between power systems and power electronics. Prerequisite: EENG480 and EENG470. 3 lecture hours; 3 semester hours.

EENG580. POWER DISTRIBUTION SYSTEMS ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN584,
This course deals with the theory and applications of problems and solutions as related to electric power distribution systems engineering from both ends: end-users like large industrial plants and electric utility companies. The primary focus of this course in on the medium voltage (4.16 kV ? 69 kV) power systems. Some references will be made to the LV power system. The course includes per-unit methods of calculations; voltage drop and voltage regulation; power factor improvement and shunt compensation; short circuit calculations; theory and fundamentals of symmetrical components; unsymmetrical faults; overhead distribution lines and power cables; basics and fundamentals of distribution protection. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG581. POWER SYSTEM OPERATION AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with EGGN587,
(I) This course presents a comprehensive exposition of the theory, methods, and algorithms for Energy Management Systems (EMS) in the power grid. It will focus on (1) modeling of power systems and generation units, (2) methods for dispatching generating resources, (3) methods for accurately estimating the state of the system, (4) methods for assessing the security of the power system, and (5) an overview of the market operations in the grid. Prerequisite: EENG480. 3 lecture hours; 3 semester hours.

EENG582. HIGH VOLTAGE AC AND DC POWER TRANSMISSION. 3.0 Semester Hrs.
Equivalent with EGGN586,
This course deals with the theory, modeling and applications of HV and EHV power transmission systems engineering. The primary focus is on overhead AC transmission line and voltage ranges between 115 kV ? 500 kV. HVDC and underground transmission will also be discussed. The details include the calculations of line parameters (RLC); steady-state performance evaluation (voltage drop and regulation, losses and efficiency) of short, medium and long lines; reactive power compensation; FACTS devices; insulation coordination; corona; insulators; sag-tension calculations; EMTP, traveling wave and transients; fundamentals of transmission line design; HV and EHV power cables: solid dielectric, oil-filled and gas-filled; Fundamentals of DC transmission systems including converter and filter. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of even years.

EENG583. ADVANCED ELECTRICAL MACHINE DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN583,
This course deals primarily with the two rotating AC machines currently utilized in the electric power industry, namely induction and synchronous machines. The course is divided in two halves: the first half is dedicated to induction and synchronous machines are taught in the second half. The details include the development of the theory of operation, equivalent circuit models for both steady-state and transient operations, all aspects of performance evaluation, IEEE methods of testing, and guidelines for industry applications including design and procurement. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG584. POWER SYSTEM RISK MANAGEMENT. 3.0 Semester Hrs.
(II) This course presents a comprehensive exposition of the theory, methods, and algorithms for risk management in the power grid. The course will focus on: (1) power system stability analysis (steady state, dynamic, and transient), (2) analysis of internal and external threats to power systems, e.g. component failures, faults, natural hazards, cyber intrusions, (3) introduction to power system security assessment, (4) fundamentals of modeling risk, vulnerability assessment and loss calculations, (5) mitigating techniques before, during and after the course of major events and disturbances. Prerequisites: EENG480, EENG481. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

EENG586. COMMUNICATION NETWORKS FOR POWER SYSTEMS. 3.0 Semester Hrs.
Advanced topics on communication networks for power systems including the fundamentals of communication engineering and signal modulation/transfer, physical layer for data transfer (e.g., wireline, wireless, fiber optics), different communication topologies for power networks (e.g., client-server, peer-to-peer), fundamentals of SCADA system, data modeling and communication services for power system applications, common protocols for utility and substation automation, and cyber-security in power networks. Prerequisites: EENG480. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG587. POWER SYSTEMS PROTECTION AND RELAYING. 3.0 Semester Hrs.
Theory and practice of power system protection and relaying; Study of power system faults and symmetrical components; Fundamental principles and tools for system modeling and analysis pertaining to relaying, and industry practices in the protection of lines, transformers, generators, motors, and industrial power systems; Introduction to microprocessor based relaying, control, and SCADA. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Spring, odd years.

EENG588. ENERGY POLICY, RESTRUCTURING AND DEREGULATION OF ELECTRICITY MARKET. 3.0 Semester Hrs.
The big picture of electric power, electricity and energy industry; Restructuring and Deregulation of electricity market; Energy Policy Acts and its impact on electricity market and pricing; Energy economics and pricing strategy; Public policy issues, reliability and security; Regulation. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG589. DESIGN AND CONTROL OF WIND ENERGY SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN589,
(II) Wind energy provides a clean, renewable source for electricity generation. Wind turbines provide electricity at or near the cost of traditional fossil-fuel fired power plants at suitable locations, and the wind industry is growing rapidly as a result. Engineering R&D can still help to reduce the cost of energy from wind, improve the reliability of wind turbines and wind farms, and help to improve acceptance of wind energy in the public and political arenas. This course will provide an overview of the design and control of wind energy systems. Offered Spring semester of odd years. 3 hours lecture; 3 semester hours.

EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG617. INTELLIGENT CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN617,
Fundamental issues related to the design on intelligent control systems are described. Neural networks analysis for engi neering systems are presented. Neural-based learning, estimation, and identification of dynamical systems are described. Qualitative control system analysis using fuzzy logic is presented. Fuzzy mathematics design of rule-based control, and integrated human-machine intelligent control systems are covered. Real-life problems from different engineering systems are analyzed. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Taught on demand.

EENG618. NONLINEAR AND ADAPTIVE CONTROL. 3.0 Semester Hrs.
Equivalent with EGGN618,
This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and the applications of this theory to adaptive control. It will focus on (1) methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations, (2) methods for designing controllers for such systems, (3) an introduction to the topic of system identification, and (4) study of the primary techniques in adaptive control, including model-reference adaptive control and model predictive control. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Spring, even numbered years.

EENG683. COMPUTER METHODS IN ELECTRIC POWER SYSTEMS. 3.0 Semester Hrs.

Equivalent with EGGN583,

This course deals with the computer methods and numerical solution techniques applied to large scale power systems. Primary focus includes load flow, short circuit, voltage stability and transient stability studies and contingency analysis. The details include the modeling of various devices like transformer, transmission lines, FACTS devices, and synchronous machines. Numerical techniques include solving a large set of linear or non-linear algebraic equations, and solving a large set of differential equations. A number of simple case studies (as per IEEE standard models) will be performed. Prerequisites: EENG583, EENG580 and EENG582 or equivalent; a strong knowledge of digital simulation techniques. 3 lecture hours; 3 semester hours. Taught on demand.

EENG698. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

Equivalent with EGGN707E,

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

ENERGY (ENGY)

ENGY200. INTRODUCTION TO ENERGY. 3.0 Semester Hrs.
Introduction to Energy. Survey of human-produced energy technologies including steam, hydro, fossil (petroleum, coal, and unconventionals), geothermal, wind, solar, biofuels, nuclear, and fuel cells. Current and possible future energy transmission and efficiency. Evaluation of different energy sources in terms of a feasibility matrix of technical, economic, environmental, and political aspects. 3 hours lecture; 3 semester hours.

ENGY310. INTRO TO FOSSIL ENERGY. 3.0 Semester Hrs.
(II) Students will learn about conventional coal, oil, and gas energy sources across the full course of exploitation, from their geologic origin, through discovery, extraction, processing, processing, marketing, and finally to their end-use in society. Students will be introduced to the key technical concepts of flow through rock, the geothermal temperature and pressure gradients, hydrostatics, and structural statics as needed to understand the key technical challenges of mining, drilling, and production. Students will then be introduced to unconventional (emerging) fossil-based resources, noting the key drivers and hurdles associated with their development. Students will learn to quantify the societal cost and benefits of each fossil resource across the full course of exploitation and in a final project will propose or evaluate a national or global fossil energy strategy, supporting their arguments with quantitative technical analysis. 3 hours lecture; 3 semester hours.

ENGY320. INTRO TO RENEWABLE ENERGY. 3.0 Semester Hrs.
(I) Survey of renewable sources of energy. The basic science behind renewable forms of energy production, technologies for renewable energy storage, distribution, and utilization, production of alternative fuels, intermittency, natural resource utilization, efficiency and cost analysis and environmental impact. 3 hours lecture; 3 semester hours.

ENGY330. ENERGY ECONOMICS. 3.0 Semester Hrs.
Equivalent with EBGN330,
(I). Study of economic theories of optimal resource extraction, market power, market failure, regulation, deregulation, technological change and resource scarcity. Economic tools used to analyze OPEC energy mergers, natural gas price controls and deregulation, electric utility restructuring, energy taxes, environmental impacts of energy use, government R&D programs, and other energy topics. Prerequisites: EBGN201 or EBGN311. 3 hours lecture; 3 semester hours.

ENGY340. NUCLEAR ENERGY. 3.0 Semester Hrs.
(I) Survey of nuclear energy and the nuclear fuel cycle including the basic principles of nuclear fission and an introduction to basic nuclear reactor design and operation. Nuclear fuel, uranium resources, distribution, and fuel fabrication, conversion and breeding. Nuclear safety, nuclear waste, nuclear weapons and proliferation as well economic, environmental and political impacts of nuclear energy. 3 hours lecture; 3 semester hours.

ENGY350. GEOTHERMAL ENERGY. 3.0 Semester Hrs.
(I) Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. 3 hours lecture; 3 semester hours.

ENGY490. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS490,MNGN490,
(II). A transdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development. Prerequisites: ENGY330/EBGN330 and one of either ENGY310, ENGY320, or ENGY340. 3 hours lecture/seminar; 3 semester hours.

ENGINEERING, DESIGN, AND SOCIETY (EDNS)

EDNS151. INTRODUCTION TO DESIGN. 3.0 Semester Hrs.
Equivalent with EPIC151,
(I, II, S) Introduction to Design teaches students how to solve open-ended problems in a hands-on manner using critical thinking and workplace skills. Students work in multidisciplinary teams to learn through doing, with emphasis on defining and diagnosing the problem through a holistic lens of technology, people and culture. Students follow a user-centered design methodology throughout the process, seeking to understand a problem from multiple perspectives before attempting to solve it. Students learn and apply specific skills throughout the semester, including: communication (written, oral, graphical), project management, concept visualization, critical thinking, effective teamwork, as well as building and iterating solutions. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS155. INTRODUCTION TO DESIGN, GRAPHICS. 1.0 Semester Hr.
Equivalent with EPIC155,
(I,II) Introduction to Design, Graphics teaches students conceptualization and visualization skills, and how to represent ideas graphically, both by hand and using computer aided design (CAD). 1 hour lecture, 1 hour lab; 1 semester hour.

EDNS156. AUTOCAD BASICS. 1.0 Semester Hr.
(I, II) This course explores the two- and three-dimensional viewing and construction capabilities of AutoCAD. Students will learn to use AutoCAD for modeling (2D line drawing, 3D construction, Rendering, Part Assembly) and will develop techniques to improve speed and accuracy. The AutoCAD certification exam will not be offered as part of this course; however, the professor will provide instructions on accessing certification options, which generally have their own fees associated with them. 3 hours lab; 1 semester hour.

EDNS157. SOLIDWORKS BASICS (FOR CERTIFICATION). 1.0 Semester Hr.
(I, II) Students will become familiar and confident with Solidworks CAD program and be able to use most of the basic functions well, including Parts, Assemblies, and Drawing Layouts. The Associate-level certification exam will be offered at the end of the course, and while there are no guarantees for students becoming certified, students will have gained the necessary skills to try. 3 hours lab; 1 semester hour.

EDNS191. INTEGRATIVE DESIGN STUDIO IA. 4.0 Semester Hrs.
Equivalent with EGGN191,
(I) (WI) Introduces students to human-centered design methodologies relative to open-ended problem solving using socially relevant challenges. Students in this first design studio course utilize a range of resources to explore ethical implications and test the logic of arguments for/against proposed design solutions. Hands-on activities and graphical visualization are utilized to approach the design process in a collaborative team environment. Students begin compiling a personal design portfolio that carries through their undergraduate studies for the Bachelor of Science in Engineering degree. 3 hours lecture; 3 hours lab; 4 semester hours.

EDNS192. INTEGRATIVE DESIGN STUDIO IB. 3.0 Semester Hrs.
Equivalent with EGGN192,
(II) (WI) Students explore and participate in design activities as a member of a multi-year, multi-discipline client project, or work on an individual or smaller team project such as the design of experiential activities or community projects. Students are challenged to evaluate the history of science and engineering and its impact on social and political systems as a foundation for creating smarter designs. Prototyping skills are utilized to explore design functionality and potential alternatives. The course continues an emphasis on technical writing along with developing other communication formats. Prerequisite: EDNS191. 2 hours lecture; 3 hours lab; 3 semester hours.

EDNS198. SPECIAL TOPCS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS200. COMMUNICATION. 3.0 Semester Hrs.
Equivalent with EGGN200,
(I, II) (WI) This course introduces future engineers to why communication matters in engineering and involves collaborative effort to convey technical details in socially embedded and socially transformative contexts. The course approach provides exposure to how engineers communicate a range and depth of sociotechnical content to varied audiences, in writing, orally, visually, electronically, and via contextual listening, and shows students ways in which communication functions via diverse genres, to multiple audiences, and for different purposes. With structured opportunity for feedback and revision, students both study and produce communication artifacts that aim to meet or exceed criteria for what constitutes legitimate evidence and context within and beyond diverse engineering fields. 3 hours lecture; 3 semester hours.

EDNS205. PROGRAMMING CONCEPTS AND ENGINEERING ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN205,
(I,II) This course provides an introduction to techniques of scientific computation that are utilized for engineering analysis, with the software package MATLAB as the primary computational platform. The course focuses on methods data analysis and programming, along with numerical solutions to algebraic and differential equations. Engineering applications are used as examples throughout the course. 3 hours lecture; 3 semester hours.

EDNS251. THE PRACTICE OF DESIGN. 3.0 Semester Hrs.
Equivalent with EPIC251,
(I, II, S) The Practice of Design builds on the design process introduced in Introduction to Design, which focuses on open-ended problem solving in which students integrate teamwork and communications with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Teams analyze team dynamics through weekly team meetings and progress reports. The course emphasizes oral presentations and builds on written communications techniques introduced in Introduction to Design. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS261. THE PRACTICE OF DESIGN: GIS. 3.0 Semester Hrs.
Equivalent with EPIC261,
(I,II,S) The Practice of Design:GIS builds on the design process learned in Introduction to Design, which focuses on open-ended problem solving where students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Practice of Design:GIS incorporates instruction and hands-on exercises in ArcGIS, a geographic information system software package, to enable students to capture, manage, analyze and display spatial data in maps and charts, to solve problems that depend on spatial analysis and orientation GIS for their design solutions. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecutre, 3 hours lab; 3 semester hours.

EDNS262. THE PRACTICE OF DESIGN: AUTOCAD. 3.0 Semester Hrs.
Equivalent with EPIC262,
(I) The Practice of Design: AutoCAD builds on the design process from Introduction to Design, which focuses on open-ended problem solving where students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. The Practice of Design: AutoCAD incorporates instruction in 3-D AutoCAD computer-aided drawing of elemental designs (structure and mechanical) and geo-spatial designs and analyses to solve problems and publish outcomes. Students are introduced to digital terrain modeling and geo-referencing concepts using AutoCAD Civil3D and raster satellite imagery. Students studying Civil Engineering, Environmental Engineering, and Mining Engineering might consider registering for this course. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS263. EPICS II MATERIALS. 3.0 Semester Hrs.
Equivalent with EPIC271,
(II) Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving where students integrate teamwork and communication with the use of computer software as tools to solve materials engineering problems. The EPICS 271 MME curriculum matches the standard EPICS 251 deliverables but with a focus on Metallurgical and Materials Engineering (MME) based projects. Previous projects have utilized areas such as mechanical testing, bio-materials, semiconductors, ceramics, and non destructive examination to address industrial, environmental, research and geopolitical open-ended problems. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS264. EPICS II: GEOLOGY GIS. 3.0 Semester Hrs.
Equivalent with EPIC264,
(II): Design EPICS II builds on the design process introduced in Design EPICS I, which focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. There are typically eight geology-based projects in the course, based on the needs of multiple outside clients. Many of the course deliverables are maps with associated data sets. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS269. EPICS II: ENGINEERING PHYSICS. 3.0 Semester Hrs.
Equivalent with EPIC269,
(I) Design EPICS II builds on the design process introduced in Design EPICS I, and focuses on open-ended problem solving in which students use teamwork to develop computer software as a tool to solve problems related to engineering physics. Students will learn basic programming skills and apply them to projects that relate to current research and applications of physics. Projects are selected to represent real world physics problems wherein creative and critical thinking skills are necessary. These projects often involve computer-based optimization to obtain a solution. Students will learn how to analyze errors in data, and their effects on data interpretation and decision-making. Engineering Physics majors are encouraged to take this course in the sophomore year. It is open to other students on a space-available basis. Prerequisite: EDNS151, EDNS155, EDNS192, or HNRS115. 2 hours lecture, 3 hours lab; 3 semester hours.

EDNS291. INTEGRATIVE DESIGN STUDIO IIA. 3.0 Semester Hrs.
Equivalent with EGGN291,
(I) Students work on an entrepreneurial or client project that may be a short-duration project or continuation of a multi-year, multi-discipline project with teams consisting of freshman to possibly senior students working on the same project, and typically student-lead designs. The course focuses on technical open-ended problem solving in which students integrate teamwork and communications with the use of computer software tools and inclusion of the greater social, political, cultural, and economic factors that ultimately determine if a design is successful. Case studies or other illustrative approaches are used to facilitate discussions on what constitutes effective or harmful designs in areas of earth, energy and environment. Information gathering and modeling are used to support problem assessment and solution exploration. Prerequisites: EDNS192 or HNRS115 or CSM192 or HASS100 and EDNS151. 3 hours lecture; 3 semester hours.

EDNS292. INTEGRATIVE DESIGN STUDIO IIB. 3.0 Semester Hrs.
Equivalent with EGGN292,
(II) Students focus on significant contribution to a design project, building proficiency as they incorporate their core and distributed science studies, and begin to integrate their studies in distributed engineering as may be appropriate to the project. Communication of the design approach is emphasized. Prerequisite: EDNS291. 3 hours lecture; 3 semester hours.

EDNS298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS301. HUMAN-CENTERED PROBLEM DEFINITION. 3.0 Semester Hrs.
Equivalent with EGGN301,
(I, II) This class will equip students with the knowledge, skills and attitudes needed to identify, define, and begin solving real problems for real people, within the socio-technical ambiguity that surrounds all engineering problems. The course will focus on problems faced in everyday life, by people from different backgrounds and in different circumstances, so that students will be able to rise to the occasion presented by future workplace challenges. By the end of this course, students will be able to recognize design problems around them, determine whether they are worth solving, and employ a suite of tools to create multiple solutions. The follow up course --"Design for People" -- will enable students to take the best solutions to the prototype phase. 3 hours lecture; 3 semester hours.

EDNS315. ENGINEERING FOR SOCIAL AND ENVIRONMENTAL RESPONSIBILITY. 3.0 Semester Hrs.
(I, II) (WI) This course explores how engineers think about and practice environmental and social responsibility, and critically analyzes codes of ethics before moving to a deeper focus on macroethical topics with direct relevance to engineering practice, environmental sustainability, social and environmental justice, social entrepreneurship, corporate social responsibility, and engagement with the public. These macroethical issues are examined through a variety of historical and contemporary case studies and a broad range of technologies. Prerequisites: HASS100, and EDNS151 or EDNS192. 3 hours lecture; 3 semester hours.

EDNS375. ENGINEERING CULTURES. 3.0 Semester Hrs.
Equivalent with LAIS375,
This course seeks to improve students? abilities to understand and assess engineering problem solving from different cultural, political, and historical perspectives. An exploration, by comparison and contrast, of engineering cultures in such settings as 20th century United States, Japan, former Soviet Union and presentday Russia, Europe, Southeast Asia, and Latin America. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS377. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS377,
(I) This course is an introduction to the relationship between engineering and sustainable community development (SCD) from historical, political, ideological, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of community and sustainable development and the role that engineering might play in them. Also students will critically explore strengths and limitations of dominant methods in engineering problem solving, design, and research for working in SCD. Students will learn to research, describe, analyze and evaluate case studies in SCD and develop criteria for their evaluation. Prerequisite: HASS!00. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

EDNS391. INTEGRATIVE DESIGN STUDIO IIIA. 3.0 Semester Hrs.
Equivalent with EGGN391,
(I) (WI) Design Practicum augments the engineering core and addresses content and depth that students may not have otherwise acquired through separate Engineering Core courses. This design studio is intended as preparation for the Design Practicum/Field Session studio EGGN392 and includes modules on technical engineering drawings, system simulation and optimization. Project management skills are emphasized. Prerequisites: EDNS292 or LAIS 200 and any EPIC 200 Level or MEGN200 or GPGN268, and EDNS200. 3 hours lecture; 3 semester hours.

EDNS392. INTEGRATIVE DESIGN STUDIO IIIB. 3.0 Semester Hrs.
Equivalent with EGGN392,
(II) (WI) Students in Design Practicum incorporate instruction from their Engineering Core to drive technical feasibility assessment of a project for a client. This studio serves as the Field Session experience for students in the BSE program and places students in a professional practice experiential environment. Teaming and leadership skills are emphasized. This course also places strong emphasis on the economic and business aspects of a project, including development of a detailed techno-economic assessment. Prerequisites: EDNS391, PHGN200, and MATH225. 3 hours lecture; 3 semester hours.

EDNS398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS401. PROJECTS FOR PEOPLE. 3.0 Semester Hrs.
Equivalent with EGGN401,
(I, II) Work with innovative organizations dedicated to community development to solve major engineering challenges. This course is open to juniors and seniors interested in engaging a challenging design problem and learning more about Human Centered Design (HCD). The course will be aimed at developing engineering solutions to real problems affecting real people in areas central to their lives. 3 hours lecture; 3 semester hours.

EDNS430. CORPORATE SOCIAL RESPONSIBILITY. 3.0 Semester Hrs.
Equivalent with LAIS430,
Businesses are largely responsible for creating the wealth upon which the well-being of society depends. As they create that wealth, their actions impact society, which is composed of a wide variety of stakeholders. In turn, society shapes the rules and expectations by which businesses must navigate their internal and external environments. This interaction between corporations and society (in its broadest sense) is the concern of Corporate Social Responsibility (CSR). This course explores the dimensions of that interaction from a multi-stakeholder perspective using case studies, guest speakers and field work. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS475. ENGINEERING CULTURES IN THE DEVELOPING WORLD. 3.0 Semester Hrs.
Equivalent with LAIS475,
An investigation and assessment of engineering problem-solving in the developing world using historical and cultural cases. Countries to be included range across Africa, Asia, and Latin America. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS478. ENGINEERING AND SOCIAL JUSTICE. 3.0 Semester Hrs.
Equivalent with LAIS478,
(II) This course offers students the opportunity to explore the relationships between engineering and social justice. The course begins with students? exploration of their own social locations, alliances and resistances to social justice through critical engagement of interdisciplinary readings that challenge engineering mindsets. Then the course helps students to understand what constitutes social justice in different areas of social life and the role that engineers and engineering might play in these. Finally, the course gives students an understanding of why and how engineering has been aligned and/or divergent from social justice issues and causes. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS479. ENGINEERS ENGAGING COMMUNITIES. 3.0 Semester Hrs.
Equivalent with LAIS479,
(I, II, S) (WI) Engineers and applied scientists face challenges that are profoundly socio-technical in nature, ranging from controversies surrounding new technologies of energy extraction that affect communities to the mercurial "social license to operate" in locations where technical systems impact people. Understanding the perspectives of communities and being able to establish positive working relationships with their members is therefore crucial to the socially responsible practice of engineering and applied science. This course provides students with the conceptual and methodological tools to engage communities in respectful and productive ways. Students will learn ethnographic field methods and participatory research strategies, and critically assess the strengths and limitations of these through a final original research project. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

EDNS480. ANTHROPOLOGY OF DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS480,
(I, II, S) (WI) Engineers and applied scientists face challenges that are profoundly socio-technical in nature, ranging from controversies surrounding new technologies of energy extraction that affect communities to the mercurial "social license to operate" in locations where technical systems impact people. Understanding the perspectives of communities and being able to establish positive working relationships with their members is therefore crucial to the socially responsible practice of engineering and applied science. This course provides students with the conceptual and methodological tools to engage communities in respectful and productive ways. Students will learn ethnographic field methods and participatory research strategies, and critically assess the strengths and limitations of these through a final original research project. Prerequisite: HASS200. Corequisite: EDNS377 or HASS325. 3 hours lecture; 3 semester hours.

EDNS491. SENIOR DESIGN I. 3.0 Semester Hrs.
Equivalent with EGGN491,
(I, II) (WI) This course is the first of a two-semester capstone course sequence giving the student experience in the engineering design process. Realistic open-ended design problems are addressed for real world clients at the conceptual, engineering analysis, and the synthesis stages and include economic and ethical considerations necessary to arrive at a final design. Students are assigned to interdisciplinary teams and exposed to processes in the areas of design methodology, project management, communications, and work place issues. Strong emphasis is placed on this being a process course versus a project course. This is a writing-across-the-curriculum course where students' written and oral communication skills are strengthened. The design projects are chosen to develop student creativity, use of design methodology and application of prior course work paralleled by individual study and research. Prerequisite: Field session appropriate to the student's specialty, for BSE Mechanical Specialty and BSME students, completion of MEGN481, for BSE Civil Specialty and BSCE students, concurrent enrollment or completion of any one of CEEN443, CEEN445, CEEN440, or CEEN415. 2 hours lecture; 3 hours lab; 3 semester hours.

EDNS492. SENIOR DESIGN II. 3.0 Semester Hrs.
Equivalent with EGGN492,
(I, II) (WI) This course is the second of a two-semester sequence to give the student experience in the engineering design process. Design integrity and performance are to be demonstrated by building a prototype or model, or producing a complete drawing and specification package, and performing pre-planned experimental tests, wherever feasible, to verify design compliance with client requirements. Prerequisite: EGGN491. 1 hour lecture; 6 hours lab; 3 semester hours.

EDNS498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

EDNS499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

EDNS577. ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS577,
Analyzes the relationship between engineering and sustainable community development (SCD) from historical, political, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of sustainability, development, and "helping", and the role that engineering might play in each. Will include critical explorations of strengths and limitations of dominant methods in engineering problem solving, design and research for working in SCD. Through case-studies, students will analyze and evaluate projects in SCD and develop criteria for their evaluation. 3 hours lecture and discussion; 3 semester hours.

EDNS598. SPECIAL TOPICS IN ENGINEERING DESIGN & SOCIETY. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EDNS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

FOREIGN LANGUAGE (LIFL)

LIFL113. SPANISH I. 3.0 Semester Hrs.
Fundamentals of spoken and written Spanish with an emphasis on vocabulary, idiomatic expressions of daily conversation, and Spanish American culture. 3 semester hours.

LIFL114. ARABIC I. 3.0 Semester Hrs.
Fundamentals of spoken and written Arabic with an emphasis on vocabulary, idiomatic expressions of daily conversation, and culture of Arabic-speaking societies. 3 semester hours.

LIFL115. GERMAN I. 3.0 Semester Hrs.
Fundamentals of spoken and written German with an emphasis on vocabulary, idiomatic expressions of daily conversation, and German culture. 3 semester hours.

LIFL119. FRENCH I. 3.0 Semester Hrs.
(I) French I provides basic instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Successful completion of French I will allow students to further their french studies in level 2. 3 hours lecture, 3 semester hours.

LIFL123. SPANISH II. 3.0 Semester Hrs.
Continuation of Spanish I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL124. ARABIC II. 3.0 Semester Hrs.
Continuation of Arabic I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and culture of Arabic speaking societies. 3 semester hours.

LIFL125. GERMAN II. 3.0 Semester Hrs.
Continuation of German I with an emphasis on acquiring conversational skills as well as further study of grammar, vocabulary, and German culture. 3 semester hours.

LIFL129. FRENCH II. 3.0 Semester Hrs.
(II) French 2 provides continued instruction in speaking, reading, listening, and writing the French language, with emphasis in class on communicating through speaking and listening skills. French and francophone culture will also be studied. Prerequisites: LIFL119. 3 hours lecture.

LIFL198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL213. SPANISH III. 3.0 Semester Hrs.
Emphasis on furthering conversational skills and a continuing study of grammar, vocabulary, and Spanish American culture. 3 semester hours.

LIFL298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL299. INDEPENDENT STUDY. 6.0 Semester Hrs.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIFL498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIFL499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEO-ENGINEERING (GOGN)

GOGN501. SITE INVESTIGATION AND CHARACTERIZATION. 3.0 Semester Hrs.
An applications oriented course covering: geological data collection, geophysical methods for site investigation; hydrological data collection; materials properties determination; and various engineering classification systems. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN502. SOLID MECHANICS APPLIED TO ROCKS. 3.0 Semester Hrs.
An introduction to the deformation and failure of rocks and rock masses and to the flow of groundwater. Principles of displacement, strain and stress, together with the equations of equilibrium are discussed. Elastic and plastic constitutive laws, with and without time dependence, are introduced. Concepts of strain hardening and softening are summarized. Energy principles, energy changes caused by underground excavations, stable and unstable equilibria are defined. Failure criteria for intact rock and rock masses are explained. Principles of numerical techniques are discussed and illustrated. Basic laws and modeling of groundwater flows are introduced. Prerequisite: Introductory Rock Mechanics. 3 hours lecture; 3 semester hours.

GOGN503. CHARACTERIZATION AND MODELING LABORATORY. 3.0 Semester Hrs.
An applications oriented course covering: Advanced rock testing procedures; dynamic rock properties determination; on-site measurements; and various rock mass modeling approaches. Presentation of data in a format suitable for subsequent engineering design will be emphasized. Prerequisite: Introductory courses in geology, rock mechanics, and soil mechanics. 3 hours lecture; 3 semester hours.

GOGN504. SURFACE STRUCTURES IN EARTH MATERIALS. 3.0 Semester Hrs.
Principles involved in the design and construction of surface structures involving earth materials. Slopes and cuts. Retaining walls. Tailing dams. Leach dumps. Foundations. Piles and piers. Extensive use of case examples. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN505. UNDERGROUND EXCAVATION IN ROCK. 3.0 Semester Hrs.
Components of stress, stress distributions, underground excavation failure mechanisms, optimum orientation and shape of excavations, excavation stability, excavation support design, ground treatment and rock pre-reinforcement, drill and blast excavations, mechanical excavation, material haulage, ventilation and power supply, labor requirements and training, scheduling and costing of underground excavations, and case histories. Prerequisites: GOGN501, GOGN502, GOGN503. 3 hours lecture; 3 semester hours.

GOGN625. GEO-ENGINEERING SEMINAR. 1.0 Semester Hr.
Discussions presented by graduate students, staff, and visiting lectures on research and development topics of general interest. Required of all graduate students in Geo-Engineering every semester, during residence. Prerequisite: Enrollment in Geo-Engineering Program. 1 semester hour upon completion of thesis or residence.

GEOCHEMICAL EXPLORATION (GEGX)

GEGX571. GEOCHEMICAL EXPLORATION. 3.0 Semester Hrs.
(I) Dispersion of trace metals from mineral deposits and their discovery. Laboratory consists of analysis and statistical interpretation of data of soils, stream sediments, vegetation, and rock in connection with field problems. Term report required. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOLOGICAL ENGINEERING (GEGN)

GEGN101. EARTH AND ENVIRONMENTAL SYSTEMS. 4.0 Semester Hrs.
Equivalent with SYGN101,
(I, II, S) Fundamental concepts concerning the nature, composition and evolution of the lithosphere, hydrosphere, atmosphere and biosphere of the earth integrating the basic sciences of chemistry, physics, biology and mathematics. Understanding of anthropological interactions with the natural systems, and related discussions on cycling of energy and mass, global warming, natural hazards, land use, mitigation of environmental problems such as toxic waste disposal, exploitation and conservation of energy, mineral and agricultural resources, proper use of water resources, biodiversity and construction. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN203. ENGINEERING TERRAIN ANALYSIS. 2.0 Semester Hrs.
(I) Analysis of landforms, geologic processes, principles of geomorphology, mapping, air photo and map interpretation, and engineering uses of geologic information.. Geomorphology of glacial, volcanic, arid, karst, and complex geological landscapes. Introduction to weathering, soils, hillslopes, and drainage systems. Prerequisite: GEGN101. Must be taken concurrently with GEGN204 and GEGN205 for GE majors. 2 hours lecture, 2 semester hours.

GEGN204. GEOLOGIC PRINCIPLES AND PROCESSES. 2.0 Semester Hrs.
(I) Introduction to advanced concepts of physical and historical geology from a scientific perspective. Development of the geologic time scale, relative time, and geochronology. Chemical composition and cycling of elements in the Earth. Plate tectonics and how tectonics influence sea-level history and sedimentation patterns. Evolution and the fossil record. Critical events in Earth history with a focus on North America and Colorado geology. Prerequisite: GEGN101. Must be taken concurrently with GEGN203 and GEGN205 for GE majors. 2 hours lecture, 2 semester hours.

GEGN205. ADVANCED PHYSICAL GEOLOGY LABORATORY. 1.0 Semester Hr.
(I) Basic geologic mapping and data gathering skills, with special emphasis on air photos and topographic and geologic maps. Course will include fieldwork in geomorphic regions of Colorado, with analysis of landforms and geologic processes. Applications of geologic information to solve geologic engineering problems. Prerequisite: GEGN101. Must be taken concurrently with GEGN203 and GEGN204 for GE majors. 3 hours laboratory, 1 semester hour.

GEGN206. EARTH MATERIALS. 3.0 Semester Hrs.
(II) Introduction to Earth Materials, emphasizing the structure, composition, formation, and behavior of minerals. Laboratories emphasize the recognition, description, and engineering evaluation of earth materials. Prerequisite: GEGN101, GEGN203, GEGN204, GEGN205. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN212. PETROLOGY FOR GEOLOGICAL ENGINEERS. 2.0 Semester Hrs.
(I) Introduction to concepts of rock forming processes as a basis for rock classification. The course will teach practical skills allowing identification of common rock types in hand specimen and in outcrop. Subsurface and nearsurface alteration and weathering processes will be covered, emphasizing recognition of secondary mineral products and the changes to the physical properties of these minerals in the rock masses. Prerequisites: GEGN206. 1 hour lecture, 3 hours lab; 2 semester hours.

GEGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN299. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN307. PETROLOGY. 3.0 Semester Hrs.
Equivalent with GEOL307,
(II) An introduction to igneous, sedimentary and metamorphic processes, stressing the application of chemical and physical mechanisms to study the origin, occurrence, and association of rock types. Emphasis on the megascopic and microscopic classification, description, and interpretation of rocks. Analysis of the fabric and physical properties. Prerequisite: GEOL321, CHGN209. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN316. FIELD GEOLOGY. 6.0 Semester Hrs.
(S) Six weeks of field work, stressing geology of the Southern Rocky Mountain Province. Mapping of igneous, metamorphic, and sedimentary terrain using air photos, topographic maps, and other methods. Diversified individual problems in petroleum geology, mining geology, engineering geology, structural geology, and stratigraphy. Formal reports submitted on several problems. Frequent evening lectures and discussion sessions. Field trips emphasize regional geology as well as mining, petroleum, and engineering projects. Prerequisites: GEGN203, GEGN204, GEGN205, GEGN206, GEGN212 or GEGN307, GEOL314, GEOL309, and GEGN317. 6 semester hours (Summer Term).

GEGN317. GEOLOGIC FIELD METHODS. 2.0 Semester Hrs.
(II) Methods and techniques of geologic field observations and interpretations. Lectures in field techniques and local geology. Laboratory and field project in diverse sedimentary, igneous, metamorphic, structural, and surficial terrains using aerial photographs and topographic maps. Geologic cross sections, maps, and reports. Weekend exercises required. Prerequisites: GEGN203, GEGN204, GEGN205, GEOL309 or GEOL308, GEGN212 or completion or concurrent enrollment in GEGN307, and completion or concurrent enrollment in GEOL314. 1 hour lecture, 8 hours field; 2 semester hours.

GEGN330. GEOSCIENTISTS THERMODYNAMICS. 3.0 Semester Hrs.
(I) Introduction to fundamental principles of thermodynamics applied to geosciences and geoengineering. Thermodynamics are used as a tool for evaluating the stability and chemical transformation of minerals and rocks, evolution of vapors and liquids and their reaction paths when subjected to different P-T geological regimes. The course will focus on basic principles of thermodynamics and make use of examples relevant to geoscientists encompassing: i) calculation of thermodynamic properties (volume, heat capacity, enthalpy and entropy) as a function of pressure, temperature and composition, ii) the study of heat transfer and volume change associated to chemical reactions and iii) evaluation of phase stabilities using Gibbs energy minimization and law of mass action. Introduction to pure phase properties, ideal and non-ideal solutions, activities, equilibrium constants, chemical potential, electrolytes, phase rule and Gibbs energy function. Prerequisites: CHGN121, CHGN122 or CHGN125, MATH111, MATH112, GEGN206. May not also receive credit for CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

GEGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

GEGN342. ENGINEERING GEOMORPHOLOGY. 3.0 Semester Hrs.
(I) Study of interrelationships between internal and external earth processes, geologic materials, time, and resulting landforms on the Earth?s surface. Influences of geomorphic processes on design of natural resource exploration programs and siting and design of geotechnical and geohydrologic projects. Laboratory analysis of geomorphic and geologic features utilizing maps, photo interpretation and field observations. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN351. GEOLOGICAL FLUID MECHANICS. 3.0 Semester Hrs.
(II) Properties of fluids; Bernoulli's energy equation, the momentum and mass equations; laminar and turbulent flow in pipes, channels, machinery, and earth materials; subcritical and supercritical flow in channels; Darcy's Law; the Coriolis effect and geostrophic flow in the oceans and atmosphere; sediment transport. Prerequisite: CEEN241. 3 hours lecture; 3 semester hours.

GEGN398. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN399. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN401. MINERAL DEPOSITS. 4.0 Semester Hrs.
(I) Introductory presentation of magmatic, hydrothermal, and sedimentary metallic ore deposits. Chemical, petrologic, structural, and sedimentological processes that contribute to ore formation. Description of classic deposits representing individual deposit types. Review of exploration sequences. Laboratory consists of hand specimen study of host rock-ore mineral suites and mineral deposit evaluation problems. Prerequisite: CHGN209, GEGN307, GEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN403. MINERAL EXPLORATION DESIGN. 3.0 Semester Hrs.
(II) (WI) Exploration project design: commodity selection, target selection, genetic models, alternative exploration approaches and associated costs, exploration models, property acquisition, and preliminary economic evaluation. Lectures and laboratory exercises to simulate the entire exploration sequence from inception and planning through implementation to discovery, with initial ore reserve calculations and preliminary economic evaluation. Prerequisite: GEGN401 and EDNS251. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN404. ORE MICROSCOPY. 3.0 Semester Hrs.
(II) Identification of ore minerals using reflected light microscopy, micro-hardness, and reflectivity techniques. Interpretation of common ore mineral textures, including those produced by magmatic segregation, open space filling, replacement, exsolution, and recrystallization. Guided research on the ore mineralogy and ore textures of classical ore deposits. Prerequisite: GEOL321, GEGN401. 6 hours lab; 3 semester hours.

GEGN432. GEOLOGICAL DATA MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) Techniques for managing and analyzing geological data, including statistical analysis procedures and computer programming. Topics addressed include elementary probability, populations and distributions, estimation, hypothesis testing, analysis of data sequences, mapping, sampling and sample representativity, linear regression, and overview of univariate and multivariate statistical methods. Practical experience with principles of software programming and statistical analysis for geological applications via suppled software and data sets from geological case histories. Prerequisites: Junior standing in Geological Engineering. 2 hours lecture; 3 hours lab; 3 semester hours.

GEGN438. PETROLEUM GEOLOGY. 4.0 Semester Hrs.
(I) Source rocks, reservoir rocks, types of traps, temperature and pressure conditions of the reservoir, theories of origin and accumulation of petroleum, geology of major petroleum fields and provinces of the world, and methods of exploration for petroleum. Term report required. Laboratory consists of study of well log analysis, stratigraphic correlation, production mapping, hydrodynamics and exploration exercises. Prerequisite: GEOL308 or GEOL309 and GEOL314 or GEOL315; and GEGN316 or GPGN486 or PEGN316. 3 hours lecture, 3 hours lab; 4 semester hours.

GEGN439. MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.
Equivalent with PEGN439,
(II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GE Majors: GEOL309, GEOL314, GEGN438, and EDNS264; GP Majors: GPGN302, and GPGN303; PE Majors: GEOL308, PEGN316 and PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN466. GROUNDWATER ENGINEERING. 3.0 Semester Hrs.
(I) Theory of groundwater occurrence and flow. Relation of groundwater to surface; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Prerequisites: Calc III (MATH213 or MATH223 or MATH224) and DiffEQ (MATH225 or MATH235) and GEGN351 or MEGN351. 3 hours lecture, 3 semester hours.

GEGN467. GROUNDWATER ENGINEERING. 4.0 Semester Hrs.
(I) Theory of groundwater occurrence and flow. Relation of groundwater to surface water; potential distribution and flow; theory of aquifer tests; water chemistry, water quality, and contaminant transport. Laboratory sessions on water budgets, water chemistry, properties of porous media, solutions to hydraulic flow problems, analytical and digital models, and hydrogeologic interpretation. Prerequisites: Calc III (MATH213, MATH223 or MATH224) and DiffEQ (MATH225 or MATH235) and GEGN351 or MEGN351. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN468. ENGINEERING GEOLOGY AND GEOTECHNICS. 4.0 Semester Hrs.
(I) Application of geology to evaluation of construction, mining, and environmental projects such as dams, water ways, tunnels, highways, bridges, buildings, mine design, and land-based waste disposal facilities. Design projects including field, laboratory, and computer analysis are an important part of the course. Prerequisite: MNGN321 and CEEN312/CEEN312L. 3 hours lecture, 3 hours lab, 4 semester hours.

GEGN469. ENGINEERING GEOLOGY DESIGN. 3.0 Semester Hrs.
(II) (WI) This is a capstone design course that emphasizes realistic engineering geologic/geotechnics projects. Lecture time is used to introduce projects and discussions of methods and procedures for project work. Several major projects will be assigned and one to two field trips will be required. Students work as individual investigators and in teams. Final written design reports and oral presentations are required. Prerequisite: GEGN468 and EDNS264. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN470. GROUND-WATER ENGINEERING DESIGN. 3.0 Semester Hrs.
(II) (WI) Application of the principles of hydrogeology and ground-water engineering to water supply, geotechnical, or water quality problems involving the design of well fields, drilling programs, and/or pump tests. Engineering reports, complete with specifications, analysis, and results, will be required. Prerequisite: GEGN467 or equivalent and EPIC264. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN473. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.
(II) Methods of field investigation, testing, and monitoring for geotechnical and hazardous waste sites, including: drilling and sampling methods, sample logging, field testing methods, instrumentation, trench logging, foundation inspection, engineering stratigraphic column and engineering soils map construction. Projects will include technical writing for investigations (reports, memos, proposals, workplans). Class will culminate in practice conducting simulated investigations (using a computer simulator). 3 hours lecture; 3 semester hours.

GEGN475. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.
(II) An introduction to Geographic Information Systems (GIS) and their applications to all areas of geology and geological engineering. Lecture topics include: principles of GIS, data structures, digital elevation models, data input and verification, data analysis and spatial modeling, data quality and error propagation, methods of GIS projects, as well as video presentations. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN481. ANALYTICAL HYDROLOGY. 3.0 Semester Hrs.
Equivalent with GEGN581,
(I) Introduction to the theory, and hydrological application of, probability, statistics, linear algebra, differential equations, numerical analysis, and integral transforms. Prerequisites: GEGN467. 3 hours lecture; 3 semester hours.

GEGN483. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.
(II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of analytical and finite-difference solutions to ground water flow problems as well as an introduction to inverse modeling. Design of computer models to solve ground water problems. Prerequisites: Familiarity with computers, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEGN499. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GEGN509. INTRODUCTION TO AQUEOUS GEOCHEMISTRY. 3.0 Semester Hrs.
(I) Analytical, graphical and interpretive methods applied to aqueous systems. Thermodynamic properties of water and aqueous solutions. Calculations and graphical expression of acid-base, redox and solution-mineral equilibria. Effect of temperature and kinetics on natural aqueous systems. Adsorption and ion exchange equilibria between clays and oxide phases. Behavior of trace elements and complexation in aqueous systems. Application of organic geochemistry to natural aqueous systems. Light stable and unstable isotopic studies applied to aqueous systems. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours.

GEGN520. INDUSTRIAL MINERALS AND ROCKS. 3.0 Semester Hrs.
Introduction to the Industrial Minerals industry via appreciation of geologic occurrence, physical and chemical material properties, mining and processing considerations, and marketing of various commodities. Development of skills in preparation of commodity surveys, reserves and resources classifications, and project appraisals. Required field trips to operational sites and trip reports. Mid-term and final exams. Individual student commodity term project and presentation. Prerequisite: Senior or graduate status in earth resources field. 3 hours lecture/seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEGN527. ORGANIC GEOCHEMISTRY OF FOSSIL FUELS AND ORE DEPOSITS. 3.0 Semester Hrs.
(II) A study of organic carbonaceous materials in relation to the genesis and modification of fossil fuel and ore deposits. The biological origin of the organic matter will be discussed with emphasis on contributions of microorganisms to the nature of these deposits. Biochemical and thermal changes which convert the organic compounds into petroleum, oil shale, tar sand, coal, and other carbonaceous matter will be studied. Principal analytical techniques used for the characterization of organic matter in the geosphere and for evaluation of oil and gas source potential will be discussed. Laboratory exercises will emphasize source rock evaluation, and oil-source rock and oil-oil correlation methods. Prerequisite: CHGN221, GEGN438. 2 hours lecture; 3 hours lab; 3 semester hours. Offered alternate years.

GEGN530. CLAY CHARACTERIZATION. 2.0 Semester Hrs.
Equivalent with GEOL530,
(I) Clay mineral structure, chemistry and classification, physical properties (flocculation and swelling, cation exchange capacity, surface area and charge), geological occurrence, controls on their stabilities. Principles of X-ray diffraction, including sample preparation techniques, data collection and interpretation, and clay separation and treatment methods. The use of scanning electron microscopy to investigate clay distribution and morphology. Methods of measuring cation exchange capacity and surface area. Prerequisites: GEGN206. 1 hour lecture, 3 hours lab; 2 semester hours.

GEGN532. GEOLOGICAL DATA ANALYSIS. 3.0 Semester Hrs.
(II) Techniques and strategy of data analysis in geology and geological engineering: basic statistics review, analysis of data sequences, mapping, sampling and sample representativity, univariate and multivariate statistics, geostatistics, and geographic information systems (GIS). Practical experience with geological applications via supplied software and data sets from case histories. Prerequisite: MATH323 or MATH530. 3 hours lecture; 3 semester hours.

GEGN561. UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 1. 0.5 Semester Hrs.
(I) This course provides students with hands-on experience with tools and skills which are commonly used in the underground construction industry. Bi-weekly labs integrate with other courses in the field of Underground Construction and Tunnel Engineering. Co-requisites: CEEN513. 1.5 hours lab; 0.5 semester hours.

GEGN562. UNDERGROUND CONSTRUCTION ENGINEERING LABORATORY 2. 0.5 Semester Hrs.
(II) This course provides students with hands-on experience with tools and skills which are commonly used in the underground construction industry. Bi-weekly labs integrate with other courses in the field of Underground Construction and Tunnel Engineering. Co-requisites: MNGN504 or CEEN523. 1.5 hours lab; 0.5 hours.

GEGN563. APPLIED NUMERICAL MODELLING FOR GEOMECHANICS. 3.0 Semester Hrs.
(I) Course focuses on a comprehensive suite of numerical analysis techniques suited to geotechnical design with a focus on excavations in rock/soil and landslides. Finite element, finite difference, discrete/distinct element and boundary element methods are all discussed with hands-on application workshops using state-of-the-art geomechanics software. Analytical models and pre- and post- processing techniques suited to typical rock engineering problems are developed through assignments. Strength criteria and non-linear inelastic constitutive models for continuum plasticity, brittle fracture and discontinuum deformation are explored in detail. Projects involving real case histories are undertaken to highlight the application of and engineering judgment associated with numerical analysis for problems involving rockmasses. Prerequisites: GEGN468, MNGN321 or CEEN312. 3 hours lecture; 3 semester hours.

GEGN570. CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY. 3.0 Semester Hrs.
(I) Case histories in geological and geotechnical engineering, ground water, and waste management problems. Students are assigned problems and must recommend solutions and/or prepare defendable work plans. Discussions center on the role of the geological engineer in working with government regulators, private-sector clients, other consultants, and other special interest groups. Prerequisite: GEGN467, GEGN468, GEGN469, GEGN470. 3 hours lecture; 3 semester hours.

GEGN571. ADVANCED ENGINEERING GEOLOGY. 3.0 Semester Hrs.
(I) Emphasis will be on engineering geology mapping methods, and geologic hazards assessment applied to site selection and site assessment for a variety of human activities. Prerequisite: GEGN468 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEGN573. GEOLOGICAL ENGINEERING SITE INVESTIGATION. 3.0 Semester Hrs.
(I) Methods of field investigation, testing, and monitoring for geotechnical and hazardous waste sites, including: drilling and sampling methods, sample logging, field testing methods, instrumentation, trench logging, foundation inspection, engineering stratigraphic column and engineering soils map construction. Projects will include technical writing for investigations (reports, memos, proposals, workplans). Class will culminate in practice conducting simulated investigations (using a computer simulator). 3 hours lecture; 3 semester hours.

GEGN575. APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS. 3.0 Semester Hrs.
(II) An introduction to Geographic Information Systems (GIS) and their applications to all areas of geology and geological engineering. Lecture topics include: principles of GIS, data structures, digital elevation models, data input and verification, data analysis and spatial modeling, data quality and error propagation, methods of GIS evaluation and selection. Laboratories will use Macintosh and DOS-based personal computer systems for GIS projects, as well as video-presentations. Visits to local GIS laboratories, and field studies will be required. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN578. GIS PROJECT DESIGN. 1-3 Semester Hr.
(I, II) Project implementation of GIS analysis. Projects may be undertaken by individual students, or small student teams. Documentation of all project design stages, including user needs assessment, implementation procedures, hardware and software selection, data sources and acquisition, and project success assessment. Various GIS software may be used; projects may involve 2-dimensional GIS, 3-dimensional subsurface models, or multi-dimensional time-series analysis. Prerequisite: none. Variable credit, 1-3 semester hours, depending on project. Offered on demand.

GEGN580. APPLIED REMOTE SENSING FOR GEOENGINEERING AND GEOSCIENCES. 3.0 Semester Hrs.
(I) This course offers an introduction to remote sensing in general and radar remote sensing and optical remote sensing in specific as well as their applications to all areas of geoengineering and geosicences. Lecture topics include: principles SAR (Synthetic Aperture Radar) and InSAR (Interferometry of Synthetic Aperture Radar) and their applications, as well as basic concepts of optical remote sensing and its application in geoengineering and geosciences. Topics include various sensors and platforms of SAR data acquisition, SAR data access, SAR data processing, data acquisition and processing of optical remote sensing images. Prerequisites: Graduate standing. 2 hours lecture, 3 hours lab, 3 semester hours.

GEGN581. ANALYTICAL HYDROLOGY. 3.0 Semester Hrs.
Equivalent with GEGN481,
(I) Introduction to the theory, and hydrological application of, probability, statistics, linear algebra, differential equations, numerical analysis, and integral transforms. The course will require more challenging assignments and exams commensurate with graduate credit. Prerequisites: GEGN467. 3 hours lecture; 3 semester hours.

GEGN582. INTEGRATED SURFACE WATER HYDROLOGY. 3.0 Semester Hrs.
Equivalent with ESGN582,
(I) This course provides a quantitative, integrated view of the hydrologic cycle. The movement and behavior of water in the atmosphere (including boundary layer dynamics and precipitation mechanisms), fluxes of water between the atmosphere and land surface (including evaporation, transpiration, precipitation, interception and through fall) and connections between the water and energy balances (including radiation and temperature) are discussed at a range of spatial and temporal scales. Additionally, movement of water along the land surface (overland flow and snow dynamics) and in the subsurface (saturated and unsaturated flow) as well as surface-subsurface exchanges and runoff generation are also covered. Finally, integration and connections within the hydrologic cycle and scaling of river systems are discussed. Prerequisites: Groundwater Engineering (GEGN466/GEGN467), Fluid Mechanics (GEGN351/ EGGN351), math up to differential equations, or equivalent classes. 3 hours lecture; 3 semester hours.

GEGN583. MATHEMATICAL MODELING OF GROUNDWATER SYSTEMS. 3.0 Semester Hrs.
(II) Lectures, assigned readings, and direct computer experience concerning the fundamentals and applications of finite-difference and finite-element numerical methods and analytical solutions to ground water flow and mass transport problems. Prerequisite: A knowledge of FORTRAN programming, mathematics through differential and integral calculus, and GEGN467. 3 hours lecture; 3 semester hours.

GEGN584. FIELD METHODS IN HYDROLOGY. 3.0 Semester Hrs.
(I) Design and implementation of tests that characterize surface and subsurface hydrologic systems, including data logger programming, sensor calibration, pumping tests, slug tests, infiltration tests, stream gauging and dilution measurements, and geophysical (EM, resistivity, and/or SP) surveys. Prerequisites: Groundwater Engineering (GEGN466/ GEGN467, Surface Water Hydrology (ESGN582) or equivalent classes. 2 hours lecture; 5 hours lab and field exercises one day of the week. Days TBD by instructor; 3 semester hours.

GEGN585. FLUID MECHANICS FOR HYDROLOGY. 2.0 Semester Hrs.
(I) This class focuses on the fundamental concepts of engineering fluid mechanics as they relate to the study of hydrology. Topics include fluid statics, dynamics, continuity, energy and momentum, dimensional analysis and open channel flow. 2 hours lecture; 2 semester hours.

GEGN586. NUMERICAL MODELING OF GEOCHEMICAL SYSTEMS. 3.0 Semester Hrs.
(II) This course provides quantitative methods for evaluating the geochemical characteristics of geological systems. The course is project based with lectures to provide information about the topic and use of geochemical modeling software. Student projects consist of chemical speciation of waters, activity diagrams, reaction progress models, water-rock interactions, sorption and surface complexation, and kinetic mineral reactions. Students complete an individual project on the geochemical system of their choice and present it to the class. Prerequisite: CEEN550 or CHGC509. 3 hours lecture, 3 semester hours. Offered spring semester, odd years.

GEGN598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN599. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN669. ADVANCED TOPICS IN ENGINEERING HYDROGEOLOGY. 1-2 Semester Hr.
(I, II) Review of current literature and research regarding selected topics in hydrogeology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 1 to 2 semester hours; may be repeated for credit.

GEGN670. ADVANCED TOPICS IN GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.
(I, II) Review of current literature and research regarding selected topics in engineering geology. Group discussion and individual participation. Guest speakers and field trips may be incorporated into the course. Prerequisite: none. 3 hours lecture; 3 semester hours. Repeatable for credit under different topics.

GEGN671. LANDSLIDES: INVESTIGATION, ANALYSIS & MITIGATION. 3.0 Semester Hrs.
(I) Geological investigation, analysis, and design of natural rock and soil slopes and mitigation of unstable slopes. Topics include landslide types and processes, triggering mechanisms, mechanics of movements, landslide investigation and characterization, monitoring and instrumentation, soil slope stability analysis, rock slope stability analysis, rock fall analysis, stabilization and risk reduction measures. Prerequisites: GEGN468, EGGN361, MNGN321, (or equivalents). 3 hours lecture; 3 semester hours.

GEGN672. ADVANCED GEOTECHNICS. 3.0 Semester Hrs.
Practical analysis and application of techniques in weak rock engineering, ground-water control in construction, fluvial stabilization and control, earthquake hazard assessment, engineering geology in construction, engineering geology in dam investigation, and other current topics in geotechnics practice. Prerequisite: GEGN468, CEEN312, CEEN312L and MNGN321. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN673. ADVANCED GEOLOGICAL ENGINEERING DESIGN. 3.0 Semester Hrs.
(II) Application of geological principles and analytical techniques to solve complex engineering problems related to geology, such as mitigation of natural hazards, stabilization of earth materials, and optimization of construction options. Design tools to be covered will include problem solving techniques, optimization, reliability, maintainability, and economic analysis. Students will complete independent and group design projects, as well as a case analysis of a design failure. 3 hours lecture; 3 semester hours. Offered alternate years.

GEGN681. VADOSE ZONE HYDROLOGY. 3.0 Semester Hrs.
(II) Study of the physics of unsaturated groundwater flow and contaminant transport. Fundamental processes and data collection methods will be presented. The emphasis will be on analytic solutions to the unsaturated flow equations and analysis of field data. Application to non-miscible fluids, such as gasoline, will be made. The fate of leaks from underground tanks will be analyzed. Prerequisites: GEGN467 or equivalent; Math through Differential Equations. 3 hours lecture; 3 semester hours.

GEGN682. FLOW AND TRANSPORT IN FRACTURED ROCK. 3.0 Semester Hrs.
(I) Explores the application of hydrologic and engineering principles to flow and transport in fractured rock. Emphasis is on analysis of field data and the differences between flow and transport in porous media and fractured rock. Teams work together throughout the semester to solve problems using field data, collect and analyze field data, and do independent research in flow and transport in fractured rock. Prerequisites: GEGN581. 3 hours lecture; 3 credit hours. Offered alternate years.

GEGN683. ADVANCED GROUND WATER MODELING. 3.0 Semester Hrs.
(II) Flow and solute transport modeling including: 1) advanced analytical modeling methods; 2) finite elements, random-walk, and method of characteristics numerical methods; 3) discussion of alternative computer codes for modeling and presentation of the essential features of a number of codes; 4) study of selection of appropriate computer codes for specific modeling problems; 5) application of models to ground water problems; and 6) study of completed modeling projects through literature review, reading and discussion. Prerequisite: GEGN509/CHGC509 or GEGN583. 2 hours lecture, 3 hours lab; 3 semester hours.

GEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEGN699. INDEPENDENT STUDY IN ENGINEERING GEOLOGY OR ENGINEERING HYDROGEOLOGY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

GEOLOGY (GEOL)

GEOL102. INTRODUCTION TO GEOLOGICAL ENGINEERING. 1.0 Semester Hr.
(II) Presentations by faculty members and outside professionals of case studies to provide a comprehensive overview of the fields of Geology and Geological Engineering and the preparation necessary to pursue careers in those fields. A short paper on an academic professional path will be required. Prerequisite: GEGN101 or concurrent enrollment. 1 hour lecture; 1 semester hour.

GEOL198. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL199. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL308. INTRODUCTORY APPLIED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.
(II) Nature and origin of structural features of Earth?s crust emphasizing structural controls on oil and gas entrapment. Structural patterns and associations are discussed in context of plate tectonic theories, using examples from across the globe. In class exercises and field projects in structural geometry, mapping and cross section construction and seismic reflection data interpretation. Course required of all PEGN and GPGN students. Prerequisite: GEGN101. 3 hours lecture; 3 semester hours.

GEOL309. STRUCTURAL GEOLOGY AND TECTONICS. 4.0 Semester Hrs.
(I) (WI) Recognition, habitat, and origin of deformational structures related to stresses and strains (rock mechanics and microstructures) and plate tectonics. Structural development of mountain belts, rift, strike-slip and salt systems. Comprehensive field and laboratory projects use descriptive geometry, stereographic projection, structural contours, map and cross section construction, air photo interpretation, and seismic reflection data analysis. Required of Geological Engineers. Prerequisite: GEGN101, GEGN203, GEGN204, GEGN205 and GEGN206 or GPGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL310. EARTH MATERIALS. 3.0 Semester Hrs.
(I) Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals and rocks. Structural features and processes are related to stress/strain theory and rock mechanics principles. Laboratories and field exercises emphasize the recognition, description and engineering evaluation of natural materials. Lectures and case study exercises present the knowledge of natural materials and processes necessary for mining engineering careers. Prerequisites: GEGN101. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL311. MINING GEOLOGY. 3.0 Semester Hrs.
(II) Introduction to Mining Geology, emphasizing the formation, distribution, engineering behavior, exploration for and geological aspects of development of ore materials. Laboratories emphasize the recognition, description and engineering evaluation of ores and their hosts. Lectures and case study exercises present the knowledge of ores and ore-forming processes necessary for mining engineering careers. Prerequisites: GEGN101 and GEOL310 or MNGN310. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL314. STRATIGRAPHY. 4.0 Semester Hrs.
(II) Lectures and laboratory and field exercises in concepts of stratigraphy and biostratigraphy, facies associations in various depositional environments, sedimentary rock sequences and geometries in sedimentary basins, and geohistory analysis of sedimentary basins. Prerequisites: GEGN101, GEGN203 or GEGN204, GEGN205. 3 hours lecture, 3 hours lab; 4 semester hours.

GEOL315. SEDIMENTOLOGY AND STRATIGRAPHY. 3.0 Semester Hrs.
(I) Integrated lecture, laboratory and field exercises on the genesis of sedimentary rocks as related to subsurface porosity and permeability development and distribution for non-geology majors. Emphasis is placed on siliciclastic systems of varying degrees of heterogeneity. Topics include diagenesis, facies analysis, correlation techniques, and sequence and seismic stratigraphy. Application to hydrocarbon exploitation stressed throughout the course. Required of all PEGN students. Prerequisite: GEGN101, PEGN308. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL321. MINERALOGY AND MINERAL CHARACTERIZATION. 3.0 Semester Hrs.
(I) Principles of mineralogy and mineral characterization. Crystallography of naturally occurring materials. Principles of crystal chemistry. Interrelationships among mineral structure, external shape, chemical composition, and physical properties. Introduction to mineral stability. Laboratories emphasize analytical methods, including X-ray diffraction, scanning electron microscopy, and optical microscopy. Prerequisite:GEGN101, CHGN122 or CHGN125, GEGN206. 2 hours lecture, 3 hours lab: 3 semester hours.

GEOL398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL410. PLANETARY GEOLOGY. 2.0 Semester Hrs.
(II) Geology of the terrestrial planets and moons, specifically the Moon and Mars. Emphasis will be placed on the geomorphology, planetary materials, geologic structure, geologic history, and natural resource potential of terrestrial planetary bodies. Lectures present the knowledge of materials, geomorphic processes, and geologic history. Prerequisite: GEGN101. 2 hours lecture: 2 semester hours.

GEOL443. UNDERGRADUATE FIELD SEMINAR. 1-3 Semester Hr.
Special advanced classroom and field programs emphasizing detailed study of some aspects of the geology of an area or region. Field studies normally conducted away from the Golden campus. Classroom course content dependent on area of study. Fees assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL444. INVERTEBRATE PALEONTOLOGY. 3.0 Semester Hrs.
(II) Fossils are the basis for establishing global correlation among Phanerozoic sedimentary rocks, and thus are critical to the reconstruction of the past 550 million years of Earth history. This is a lecture elective course that will aid in rounding out undergraduate Earth science/ engineering geological knowledge. Fossil preservation, taphonomy, evolution, mass extinctions, biostratigraphy, graphic correlation, invertebrate phyla and their geologic history and evolution. Prerequisites: GEGN204, GEGN205, GEGN206. 3 hours lecture; 3 semester hours.

GEOL470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
(II) Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

GEOL498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GEOL499. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GEOL501. APPLIED STRATIGRAPHY. 4.0 Semester Hrs.
(I) Review of basic concepts in siliciclastic and carbonate sedimentology and stratigraphy. Introduction to advanced concepts and their application to exploration and development of fossil fuels and stratiform mineral deposits. Modern facies models and sequence-stratigraphic concepts applied to solving stratigraphic problems in field and subsurface settings. Prerequisites: GEOL314 or equivalent. 3 hours lecture, 4 hours lab; 4 semester hours.

GEOL502. STRUCTURAL METHODS FOR SEISMIC INTERPRETATION. 3.0 Semester Hrs.
(I) A practical course that covers the wide variety of structural methods and techniques that are essential to produce a valid and coherent interpretation of 2D and 3D seismic reflection data in structurally complex areas. Topics covered include: Extensional tectonics, fold and thrust belts, salt tectonics, inversion tectonics and strike-slip fault systems. Laboratory exercises are based on seismic datasets from a wide variety of structural regimes from across the globe. The course includes a 4 day field trip to SE Utah. Prerequisite: GEOL309 and GEOL314 or GEOL315, or equivalents. 3 hours lecture/lab; 3 semester hours.

GEOL503. INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA. 3.0 Semester Hrs.
(II) INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA-A PRACTICAL COURSE IN SEISMIC INTERPRETATION OF GLOBAL DATASETS. A practical course in workstation based, integrated geological interpretation of 3D seismic reflection data. Course builds directly on the seismic interpretation skills learnt in the prerequisite GEOL502 Structural Methods for Seismic Interpretation. Key concepts developed in this course are: making internally consistent interpretations of complex 3D datasets and developing integrated geological (structural and stratigraphic) interpretations of 3D seismic data. Prerequisite: GEOL502. 3 hours lecture/lab; 3 semester hours.

GEOL505. ADVANCED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.
(I) Advanced Structural Geology builds on basic undergraduate Structural Geology. Structures such as folds, faults, foliations, lineations and shear zones will be considered in detail. The course focuses on microstructures, complex geometries and multiple generations of deformation. The laboratory consists of microscopy, in-class problems, and some field-based problems. Prerequisites: GEGN307, GEOL309, GEGN316, GEOL321, or equivalents. 2 hours lecture, 2 hours lab, and field exercise; 3 semester hours.

GEOL512. MINERALOGY AND CRYSTAL CHEMISTRY. 3.0 Semester Hrs.
(I) Relationships among mineral chemistry, structure, crystallography, and physical properties. Systematic treatments of structural representation, defects, mineral stability and phase transitions, solid solutions, substitution mechanisms, and advanced methods of mineral identification and characterization. Applications of principles using petrological and environmental examples. Prerequisites: GEOL321, DCGN209 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL513. HYDROTHERMAL GEOCHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGC513,
(II) Geochemistry of high-temperature aqueous systems. Examines fundamental phase relationships in model systems at elevated temperatures and pressures. Major and trace element behavior during fluid-rock interaction. Theory and application of stable isotopes as applied to hydrothermal mineral deposits. Review of the origin of hydrothermal fluids and mechanisms of transport and deposition of ore minerals. Includes the study of the geochemistry of magmatic aqueous systems, geothermal systems, and submarine hydrothermal vents. Prerequisites: GEGN401. 2 hours lecture, 3 hours lab; 3 semester hours.

GEOL514. BUSINESS OF ECONOMIC GEOLOGY. 3.0 Semester Hrs.
Examines the business side of mineral exploration including company structure, fundraising, stock market rules and regulations, and legal environment. Reviews the types of minerals exploration companies, differences between mineral sectors, rules and practices of listing a minerals company on a stock exchange, and legal requirements of listing and presenting data to stockholders. The course is centered on lectures by industry representatives from the Denver area. Includes participation in a technical conference in Vancouver or Toronto and meetings with lawyers, stockbrokers, and geoscientists working in the mineral industry. Prerequisites: GEGN401. 3 hours lecture and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL515. ADVANCED MINERAL DEPOSITS. 3.0 Semester Hrs.
(I) Geology of mineral systems at a deposit, district, and regional scale formed by magmatic-hydrothermal, sedimentary/basinal, and metamorphic processes. Emphasis will be placed on a systems approach to evaluating metal and sulfur sources, transportation paths, and traps. Systems examined will vary by year and interest of the class. Involves a team-oriented research project that includes review of current literature and laboratory research. Prerequisites: GEGN401. 1 hour lecture, 5 hours lab; 3 semester hours. Repeatable for credit.

GEOL517. FIELD METHODS FOR ECONOMIC GEOLOGY. 3.0 Semester Hrs.
(II) Methods of field practices related to mineral exploration and mining. Lithology, structural geology, alteration, and mineralization vein-type precious metal deposits. Mapping is conducted both underground at the Edgar Test Mine and above ground in the Idaho Springs area. Drill core and rock chips from different deposit types are utilized. Technical reports are prepared for each of four projects. Class is run on Saturday (9 am-4 pm) throughout the semester. Prerequisites: GEGN401. 6 hours lab and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

GEOL518. MINERAL EXPLORATION. 3.0 Semester Hrs.
(II) Mineral industry overview, deposit economics, target selection, deposit modeling, exploration technology, international exploration, environmental issues, program planning, proposal development. Team development and presentation of an exploration proposal. Prerequisite: GEOL515, GEOL520, or equivalent. 2 hours lecture/seminar, 3 hours lab; 3 semester hours. Offered when student demand is sufficient.

GEOL519. ABITIBI GEOLOGY AND EXPLORATION FIELD SCHOOL. 3.0 Semester Hrs.
(II, S) Methods of field practices related to mineral exploration and mining. Regional and deposit-scale geology of Archean mineral deposits, including lode gold deposits and volcanic-hosted massive sulfide deposits. Includes mineral prospect evaluation, structural geology, physical volcanology, deposit definition, alteration mapping, mining methods, ore processing, and metallurgy. Core logging, underground stope mapping, open pit mapping, lithogeochemical sampling, and field-analytical techniques. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 14-day field trip is run in the summer semester. Each day includes up to 4 hours of instruction in the field and 4 hours of team-oriented field exercises. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient.

GEOL520. NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS. 3.0 Semester Hrs.
(I, II) Each topic unique and focused on a specific mineral deposit type or timely aspects of economic geology. Review of the geological and geographic setting of a specific magmatic, hydrothermal, or sedimentary mineral deposit type. Detailed study of the physical and chemical characteristics of selected deposits and mining districts. Theory and application of geological field methods and geochemical investigations. Includes a discussion of genetic models, exploration strategies, and mining methods. Prerequistes: GEGN401. 2 hours lecture; 2 semester hours. Repeatable for credit.

GEOL521. FIELD AND ORE DEPOSIT GEOLOGY. 3.0 Semester Hrs.
(I, S) Field study of major mineral deposit districts inside and outside of the USA. Examines regional and deposit-scale geology. Underground and open pit mine visits and regional traverses. Topics addressed include deposit definition, structural geology, alteration mapping, mining methods, and ore processing. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 10-14 day field trip is run in the summer semester. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient. Repeatable for credit.

GEOL522. TECTONICS AND SEDIMENTATION. 3.0 Semester Hrs.
(II) Application and integration of advanced sedimentologic and stratigraphic concepts to understand crustal deformation at a wide range of spatial- and time-scales. Key concepts include: growth-strata analysis, interpretation of detrital composition (conglomerate unroofing sequences and sandstone provenance trends), paleocurrent deflection and thinning trends, tectonic control on facies distribution and basic detrital zircon and fission track analysis. Students will read a wide range of literature to explore the utility and limitation of traditional "tectonic signatures" in stratigraphy, and will work on outcrop and subsurface datasets to master these concepts. Special attention is paid to fold-thrust belt, extensional and salt-related deformation. The course has important applications in Petroleum Geology, Geologic Hazards, and Hydrogeology. Required: 2-3 fieldtrips, class presentations, and a final paper that is written in a peer-reviewed journal format. Prerequisites: GEOL314 or equivalent, and GEOL309 or equivalent. 3 hours lecture and seminar; 3 semester hours. Offered even years.

GEOL523. REFLECTED LIGHT AND ELECTRON MICROSCOPY. 2.0 Semester Hrs.
(I) Theoretical and practical aspects of reflected light and electron microscopy. Emphasis will be placed on applications to ore deposit exploration and research. Lecture and discussion topics will highlight both standard and new techniques and instrumentation including SEM and QEMSCAN, as well as key questions in mineral deposit genesis which can be addressed using reflected light and electron microscopy. Includes detailed study of a selected suite of samples, with emphasis on mineral identification, textural relationships, paragenetic sequences, and mineral chemistry. Course culminates in a project. Prerequisites: GEGN401. 1 hour lecture; 3 hours lab; 2 semester hours.

GEOL525. PRINCIPLES OF METAMORPHIC GEOLOGY. 3.0 Semester Hrs.
(I) Study of metamorphic processes and products that occur on Earth at the micro- to the macro-scale. Areas of focus include (a) the nature of metamorphism in subduction zones and continental interiors, (b) the mechanisms and physico-chemical effects of fluid-rock and melt-rock interactions, (c) links between metamorphism and ore-forming processes, and (d) combining metamorphism with geochemistry, isotope geochronology, and structural geology to quantify the tectonothermal evolution of the lithosphere throughout space and time. Laboratory exercises emphasize the examination, identification, and interpretation of metamorphic minerals and microstructures in hand sample and down the microscope, and the calculation and application of thermodynamically constrained phase equilibria to describe and predict the pressure-temperature evolution of rocks and terranes. Short field excursions to local sites of metamorphic interest. Offered every other year. Prerequisites: GEOL321 and GEGN307. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL535. LITHO ORE FORMING PROCESSES. 3.0 Semester Hrs.
(I, II, S) Lithogeochemistry is the study of fluid-rock interaction in hydrothermal systems from a mineralogical perspective. Practical course on numerical modeling of fluid-rock interaction combined with observations of mineral assemblages in rocks and thin sections taking hydrothermal ore deposits as test examples including pegmatites and veins, greisen alteration, porphyry systems and REE deposits. Mechanisms of metal complexation, transport and mineralization processes in hydrothermal fluids are connected to mineral alteration textures, mineral/rock geochemistry and mineral paragenesis. Includes a mine visit if available. Prerequisites: GEOL321, GEGN401. 2 hours lecture; 3 hours lab, 3 semester hours.

GEOL540. ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY. 3.0 Semester Hrs.
(II) A study of the principles of geochronology and stable isotope distributions with an emphasis on the application of these principles to important case studies in igneous petrology and the formation of ore deposits. U, Th, and Pb isotopes, K-Ar, Rb-Sr, oxygen isotopes, hydrogen isotopes, and carbon isotopes included. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL550. INTEGRATED BASIN MODELING. 3.0 Semester Hrs.
(I) This course introduces students to principal methods in computer-based basin modeling: structural modeling and tectonic restoration; thermal modeling and hydrocarbon generation; and stratigraphic modeling. Students apply techniques to real data set that includes seismic and well data and learn to integrate results from multiple approaches in interpreting a basin's history. The course is primarily a lab course. Prerequisite: none. A course background in structural geology, sedimentology/stratigraphy or organic geochemistry will be helpful. 1 hour lecture, 5 hours labs; 3 semester hours.

GEOL551. APPLIED PETROLEUM GEOLOGY. 3.0 Semester Hrs.
(II) Subjects to be covered include computer subsurface mapping and cross sections, petrophysical analysis of well data, digitizing well logs, analyzing production decline curves, creating hydrocarbon-porosity-thickness maps, volumetric calculations, seismic structural and stratigraphic mapping techniques, and basin modeling of hydrocarbon generation. Students are exposed to three software packages used extensively by the oil and gas industry. Prerequisite: GEGN438 or GEOL609. 3 hours lecture; 3 semester hours.

GEOL552. UNCONVENTIONAL PETROLEUM SYSTEMS. 3.0 Semester Hrs.
(II) Unconventional petroleum systems have emerged as a critical and indispensable part of current US production and potential future reserves. Each of the 5 unconventional oil and 4 unconventional gas systems will be discussed: what are they, world wide examples, required technology to evaluate and produce, environmental issues, and production/resource numbers. The oil part of the course will be followed by looking at cores from these systems. The gas part of the course will include a field trip to the Denver, Eagle, and Piceance Basins in Colorado to see outstanding outcrops of actual producing units. Prerequisites: GEGN438 or GEOL609, GEGN527. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL553. GEOLOGY AND SEISMIC SIGNATURES OF RESERVOIR SYSTEMS. 3.0 Semester Hrs.
(II) This course is a comprehensive look at the depositional models, log signatures, characteristics, and seismic signatures for all the main reservoirs we explore for and produce from in the subsurface. The first half is devoted to the clastic reservoirs (12 in all); the second part to the carbonate reservoirs (7 total). The course will utilize many hands-on exercises using actual seismic lines for the various reservoir types. Prerequisites: GEOL501 or GEOL314. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL555. STRUCTURAL FIELD RESEARCH. 4.0 Semester Hrs.
(I) This course focuses on geological field work along the Colorado Front Range through inquiry-based research and hypothesis-testing. The type of problems students will work on will vary from more applied problems (e.g. centered around the Edgar mine) or more academic/scientific orientated problems, depending on the student?s interest. The class will be split up in groups of students with similar interests. In the first part of the course, we take an introductory two-day field trip, and students will review existing literature and maps and write a brief research proposal including hypotheses, tests and a work plan for the remainder of the course. The second part of the course will focus on field work. During the last part of the course, students prepare a geological map and appropriate cross sections, and a report presenting rock descriptions, structural analysis, a geological history, and interpretation of results in the context of the hypotheses posed. Prerequisites: (need previous field experience such as a field course, and a course in structural geology and one in earth materials). 2 hours lecture, 6 hours lab; 4 semester hours.

GEOL560. IMPERIAL BARREL AAPG COMPETITION CLASS. 3.0 Semester Hrs.
(II) The course is designed for geoscience students to evaluate as a team a geophysical and geological dataset. The date set consists of seismic, well data, geochemical information, and geophysical logs. The class provides students with an insight into the hydrocarbon exploration business. A petroleum geology background is useful but not required. A team will compete at the Rocky Mountain Section competition and go onto the Annual American Association of Petroleum Geologist (AAPG) meeting competition if they win the section competition. The class is intended for graduate students only. 3 hours lecture; 3 semester hours.

GEOL565. RISKS AND VOLUMES ASSESSMENT FOR CONVENTIONAL AND UNCONVENTIONAL PROSPECTS AND PLAYS. 3.0 Semester Hrs.
(II) Students learn to translate geological knowledge into sound and realistic numbers and ranges for consistent risk and volume assessment of exploration prospects. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

GEOL570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GEOL575. PETROLEUM SYSTEMS ANALYSIS. 3.0 Semester Hrs.
(I, II, S) The goal is to learn how to analyze petroleum systems and use tools of petroleum geochemistry and basin modeling to find, appraise and produce oil and gas. Prerequisites: GEGN438. 3 hours lecture; 3 semester hours.

GEOL585. APPLICATION OF SEISMIC GEOMORPHOLOGY. 3.0 Semester Hrs.
(I) Seismic Geomorphology is the study of landforms imaged in 3-D seismic data, for the purpose of understanding the history, processes and fill architecture of a basin. This course will review both qualitative and quantitative approaches to interpreting and applying seismic geomorphologic observations in basin exploration and development. Examples from Gulf of Mexico, Indonesia, Trinidad, Morocco, New Zealand and other basins of the world will be used to illustrate the techniques for interpreting the depositional elements of fluvial, deltaic, shoreline, shelf, deep water clastic systems, as well as delineating geohazards, and for quantifying and using those data to predict reservoir distribution and architecture, body geometries, planning field developments and assessing uncertainty. This introductory look at the tool of seismic geomorphology is suitable for any geoscientists or engineers looking to enhance their understanding of ancient depositional systems imaged in seismic data. 3 hours lecture; 3 semester hours.

GEOL598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL599. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL601. CORE TO OUTCROP STRATIGRAPHY. 2.0 Semester Hrs.
(II) A seminar series integrating core and outcrop observations with class discussions. Topics range from global to regional scale tectono-stratigraphy to process sedimentology. Discussions are based on reading journal papers combined with core observations. Field trip encompasses a series of outcrop-based projects/exercises. Prerequisite: GEOL501. 2 hours seminar; 2 semester hours.

GEOL608. HISTORY OF GEOLOGICAL CONCEPTS. 3.0 Semester Hrs.
(I) Lectures and seminars concerning the history and philosophy of the science of geology; emphasis on the historical development of basic geologic concepts. Course is an elective for doctoral candidates in department. 3 hours lecture; 3 semester hours.

GEOL609. ADVANCED PETROLEUM GEOLOGY. 3.0 Semester Hrs.
(II) Subjects to be covered involve consideration of basic chemical, physical, biological and geological processes and their relation to modern concepts of oil/gas generation (including source rock deposition and maturation), and migration/accumulation (including that occurring under hydrodynamic conditions). Concepts will be applied to the historic and predictive occurrence of oil/gas to specific Rocky Mountain areas. In addition to lecture attendance, course work involves review of topical papers and solution of typical problems. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

GEOL610. ADVANCED SEDIMENTOLOGY. 3.0 Semester Hrs.
(I) Keynote lectures, mixed with discussions, in-class exercises, core and field observations in a seminar series on sedimentology. Introduction to current hot topics in sedimentology, and discussions on fundamental principles. Specific topics vary yearly depending on most recent advancements and course participant?s interests. Quantitative sedimentology. Applications of sedimentology. All seminars are based on reading and discussing journal papers. Field trip to a modern environment. Essays and presentations required. Prerequisite: GEOL501. Acceptable to take GEOL610 at the same time, as GEOL501. 3 hours lecture and seminar; 3 semester hours. Offered alternate years.

GEOL611. SEQUENCE STRATIGRAPHY IN SEISMIC, WELL LOGS, AND OUTCROP. 3.0 Semester Hrs.
(I) Keynote lectures and a seminar series on the sequence stratigraphy of depositional systems, including both siliciclastics and carbonates and how they behave in changing sea-level, tectonic subsidence, and sediment supply conditions. Application of sequence stratigraphy concepts to reflection seismic, well-log, and outcrop datasets. Field trip and report required. Prerequisite: GEOL501. 3 hours lecture and seminar; 3 semester hours.

GEOL613. GEOLOGIC RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.
(I, II) Principles and practice of characterizing petro leum reservoirs using geologic and engineering data, including well logs, sample descriptions, routine and special core analysis and well tests. Emphasis is placed on practical analysis of such data sets from a variety of clastic petroleum reservoirs worldwide. These data sets are integrated into detailed characterizations, which then are used to solve practical oil and gas field problems. Prerequisites: GEGN438, GEOL501, GEOL505 or equivalents. 3 hours lecture; 3 semester hours.

GEOL617. THERMODYNAMICS AND MINERAL PHASE EQUILIBRIA. 3.0 Semester Hrs.
(I) Basic thermodynamics applied to natural geologic systems. Evaluation of mineral-vapor mineral solution, mineral-melt, and solid solution equilibria with special emphasis on oxide, sulfide, and silicate systems. Experimental and theoretical derivation, use, and application of phase diagrams relevant to natural rock systems. An emphasis will be placed on problem solving rather than basic theory. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOL621. PETROLOGY OF DETRITAL ROCKS. 3.0 Semester Hrs.
(II) Compositions and textures of sandstones, siltstones, and mudrocks. Relationship of compositions and textures of provenance, environment of deposition, and burial history. Development of porosity and permeability. Laboratory exercises emphasize use of petrographic thin sections, x-ray diffraction analysis, and scanning electron microscopy to examine detrital rocks. A term project is required, involving petrographic analysis of samples selected by student. Pre-requisites: GEGN206 , GEOL321 or equivalent. 2 hours lecture and seminar, 3 hours lab; 3 semester hours. Offered on demand.

GEOL624. CARBONATE SEDIMENTOLOGY AND PETROLOGY. 3.0 Semester Hrs.
(II) Processes involved in the deposition of carbonate sediments with an emphasis on Recent environments as analogs for ancient carbonate sequences. Carbonate facies recognition through bio- and lithofacies analysis, three-dimensional geometries, sedimentary dynamics, sedimentary structures, and facies associations. Laboratory stresses identification of Recent carbonate sediments and thin section analysis of carbonate classification, textures, non-skeletal and biogenic constituents, diagenesis, and porosity evolution. Prerequisite: GEOL321 and GEOL314. 2 hours lecture/seminar, 2 hours lab; 3 semester hours.

GEOL628. ADVANCED IGNEOUS PETROLOGY. 3.0 Semester Hrs.
(I) Igneous processes and concepts, emphasizing the genesis, evolution, and emplacement of tectonically and geochemically diverse volcanic and plutonic occurrences. Tectonic controls on igneous activity and petrochemistry. Petrographic study of igneous suites, mineralized and non-mineralized, from diverse tectonic settings. Prerequisites: GEOL321, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

GEOL642. FIELD GEOLOGY. 1-3 Semester Hr.
(S) Field program operated concurrently with GEGN316 field camp to familiarize the student with basic field technique, geologic principles, and regional geology of Rocky Mountains. Prerequisite: Undergraduate degree in geology and GEGN316 or equivalent. During summer field session; 1 to 3 semester hours.

GEOL643. GRADUATE FIELD SEMINARS. 1-3 Semester Hr.
(I, II, S) Special advanced field programs emphasizing detailed study of some aspects of geology. Normally conducted away from the Golden campus. Prerequisite: Restricted to Ph.D. or advanced M.S. candidates. Usually taken after at least one year of graduate residence. Background requirements vary according to nature of field study. Fees are assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

GEOL645. VOLCANOLOGY. 3.0 Semester Hrs.
(II) Assigned readings and seminar discussions on volcanic processes and products. Principal topics include pyroclastic rocks, craters and calderas, caldron subsidence, diatremes, volcanic domes, origin and evolution of volcanic magmas, and relation of volcanism to alteration and mineralization. Petrographic study of selected suites of lava and pyroclastic rocks in the laboratory. Prerequisite: none. 1 hour seminar, 6 hours lab; 3 semester hours.

GEOL653. CARBONATE DIAGENESIS AND GEOCHEMISTRY. 3.0 Semester Hrs.
(II) Petrologic, geochemical, and isotopic approaches to the study of diagenetic changes in carbonate sediments and rocks. Topics covered include major near-surface diagenetic environments, subaerial exposure, dolomitization, burial diagenesis, carbonate aqueous equilibria, and the carbonate geochemistry of trace elements and stable isotopes. Laboratory stresses thin section recognition of diagenetic textures and fabrics, x-ray diffraction, and geochemical/isotopic approaches to diagenetic problems. Prerequisites: GEOL624. 2 hours lecture; 3 hours lab; 3 semester hours.

GEOL660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION ENGINEERING. 3.0 Semester Hrs.
Equivalent with PEGN660,
(II) An introduction to the reservoir characterization of carbonate rocks, including geologic description, petrophysics, and production engineering. Develops an understanding of the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises that include reflection seismic, well-log, and core data. 3 hours lecture; 3 semester hours.

GEOL698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GEOL699. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GEOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

GEOPHYSICAL ENGINEERING (GPGN)

GPGN101. INTRODUCTION TO GEOPHYSICS: GEOPHYSICS AND SOCIETY. 3.0 Semester Hrs.
(I) This is a discovery course designed to introduce freshmen to the science of geophysics in the context of society and humans' interaction with the Earth. Students will explore geophysical measurements and characterization of earth properties and processes that have the greatest impact on the development of human civilization. Examples include characterizing earthquakes and volcanic eruptions, imaging energy resources deep within the earth, measuring the impacts of climate change on the ice sheets, and evaluation of water resources. 3 hours lecture; 3 semester hours.

GPGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN200. INTRODUCTION TO GEOPHYSICS. 3.0 Semester Hrs.
(I) (WI) This is a discovery course designed to introduce sophomores to the science of geophysics in the context of the whole-earth system. Students will explore the fundamental observations from which physical and mathematical inferences can be made regarding the Earth?s origin, structure, and processes. Examples of such observations are earthquake records; geodetic and gravitational data, such as those recorded by satellites; magnetic measurements; and greenhouse gases in the atmosphere. Learning will take place through the examination of selected topics that may vary from one semester to the next. Examples of such topics are: earthquake seismology, geomagnetism, geodynamics, and climate change. 3 hours, lecture, 3 semester hours.

GPGN228. INTRODUCTION TO ROCK PHYSICS. 3.0 Semester Hrs.
(I) Introduction to sediment and rock properties, their measurements, and geophysical operations. Course will introduce physical and mathematical framework, quantitative interpretations, and provide framework for multi-physics approaches, data interpretation, and data inversion to help us understand the physical properties of the subsurface. Topics covered will include mineralogy, porosity, density, pore shape/size, pore fluids, permeability, compressibility, stress, and strength and how they can be measured with experiments and approximated with geophysical techniques. 2 hours lecture; 3 hours lab; 3 semester hours.

GPGN229. MATHEMATICAL GEOPHYSICS. 3.0 Semester Hrs.
(II) This course will address how specific mathematical approaches are used to understand and to solve geophysical problems. Topics that will be used in a geophysical context include continuum mechanics, linear algebra, vector calculus, complex variables, Fourier series, partial differential equations, probability, the wave equation, and the heat equation. Prerequisites: MATH111, MATH112, MATH213, PHGN100, PHGN200. Corequisites: MATH225. 3 hours lecture; 3 semester hours.

GPGN268. GEOPHYSICAL DATA ANALYSIS. 3.0 Semester Hrs.
Equivalent with EPIC268,
(II) Geophysical Data Analysis focuses on open-ended problem solving in which students integrate teamwork and communication with the use of computer software as tools to solve engineering problems. Computer applications emphasize information acquisition and processing based on knowing what new information is necessary to solve a problem and where to find the information efficiently. Students work on projects from the geophysical engineering practice in which they analyze (process, model, visualize) data. In their projects, students encounter limitations and uncertainties in data and learn quantitative means for handling them. They learn how to analyze errors in data, and their effects on data interpretation and decision making. 3 lecture hours; 3 semester hours.

GPGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN314. APPLIED GEOPHYSICS. 4.0 Semester Hrs.
(II) Applied Geophysics is an introductory course on the theory and application of gravity, magnetic, electrical, electromagnetic, and seismic methods for imaging the Earth's subsurface. These tools are employed in various geotechnical and environmental engineering problems, resource exploration and production monitoring, geothermal site characterization, hazards, and humanitarian efforts. Through the combination of three one-hour lectures and one three-hour lab each week, the students are provided with the fundamental theory and hands on field experiments for each of these techniques including the principles, instrumentation, and procedures of data acquisition, analysis, and interpretation. Prerequisites: MATH213, MATH225, GPGN228, GPGN328, CSCI250. Co-requisite: GPGN329. 3 hours lecture; 3 hours lab; 4 semester hours.

GPGN328. PHYSICS OF THE EARTH - I. 3.0 Semester Hrs.
(I) This course is the first part of a two-course sequence on Physics of the Earth and will introduce the static fields including the electrostatics, steady state current flow in conductive media, magnetostatics, and gravitational field as used in probing the interior of the Earth and physical processes therein. The spatial context will be earth?s lithosphere and the associated geoscientific problems arise from a wide range of disciplines including environmental problems, hydrology, minerals and energy exploration, hydrology, tectonics, and climate science. The course will discuss static field theory, their interaction with different physical properties of earth materials, and the use of these fields in imaging, characterizing, and monitoring structures and processes in the earth lithosphere and on the interface between atmosphere and crust. Prerequisites: PHGN200, GPGN229. 3 hours lecture; 3 semester hours.

GPGN329. PHYSICS OF THE EARTH - II. 3.0 Semester Hrs.
(II) The second half of Physics of the Earth will aim to give a global perspective to Earth?s formation and evolution. Starting from conservation laws and continuum mechanics, Earth?s dynamic fields (theory of seismic and electromagnetic wave propagation) will be covered in the context of solid-Earth geophysics and integrated with various geophysical observations & measurements; the Earth seen by the waves, inferring the structure and composition of the interior of planetary bodies from crust to core, physical & thermo-chemical processes in mantle and core shaping Earth?s surface and magnetic field, planetary cooling, ?hot topics? and current challenges in illuminating Earth?s deep structure, modern computational techniques that are used to improve our understanding of Earth?s interior and history. Prerequisites: PHGN200, MATH225, GPGN229, GPGN328. 3 hours lecture; 3 semester hours.

GPGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

GPGN350. SCIENCE AND COMMUNICATION SKILLS. 3.0 Semester Hrs.
(I) (WI) This class covers the basic skills needed for research and for communicating the results of the research. The class covers hands-on elements of doing research, such as choosing a research topic, generating research questions, making a work plan, dealing with the ambiguity and hurdles of research, research ethics, as well as publishing scientific papers, scientific writing, giving oral communications, and writing research proposals. In addition, the class covers career-oriented topics such as choosing a program for graduate studies, working with an advisor, and applying for a job. Students acquire hands-on experience by choosing a research project, making a work plan, writing a proposal, and presenting that proposal. 3 hours lecture; 3 semester hours.

GPGN398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN404. DIGITAL SIGNAL PROCESSING. 3.0 Semester Hrs.
(II) The fundamentals of 1-D digital signal processing as applied to geophysical investigations are studied. Students explore the mathematical background and practical consequences of Fourier series and 1D/2D Fourier transforms, linear time-invariant (LTI) systems, convolution and deconvolution, properties of discrete systems, sampling theorem and signal reconstruction, Z-Transform, discrete-time Fourier transform, discrete Fourier series and discrete Fourier transform, windowing and spectrograms, realization of digital filters, FIR filter design and IIR filter design Emphasis is placed on applying the knowledge gained in lecture to exploring practical signal processing issues.
This is done through homework and in-class practicum assignments requiring the programming and testing of algorithms discussed in lecture. Prerequisite: CSCI250. 2 hours lecture; 3 hours lab; 3 semester hours.

GPGN409. INVERSION. 3.0 Semester Hrs.
(I) A study of the fundamentals of inverse problem theory as applied to geophysics. The inversion technology has applicability in all fields of geophysical application, regardless of the physics employed, as well as in non-geophysical data analysis. The course covers fundamental concepts of inversion in the probabilistic and deterministic frameworks, as well as practical methods for solving discrete inverse problems. Topics studied include model discretization, Bayesian inversion, optimization criteria and methods, regularization techniques, error and resolution analysis. Weekly homework assignments addressing either theoretical or numerical problems through programming assignments illustrate the concepts discussed in class. Knowledge of the Python programming language is assumed. Prerequisites: GPGN229, MATH332, GPGN335, CSCI250. Co-requisite: GPGN435. 3 hours lecture; 3 semester hours.

GPGN411. GRAVITY AND MAGNETIC METHODS. 3.0 Semester Hrs.
Equivalent with GPGN414,
(I) Instrumentation for land surface, borehole, sea floor, sea surface, and airborne operations. Reduction of observed gravity and magnetic values. Theory of potential field effects of geologic distributions. Methods and limitations of interpretation. Prerequisite: GPGN314. 3 hours lecture; 3 semester hours.

GPGN419. INTRODUCTION TO FORMATION EVALUATION AND WELL LOGGING. 3.0 Semester Hrs.
(I, II) An introduction to well logging methods, including the relationship between measured properties and reservoir properties. Analysis of log suites for reservoir size and content. Graphical and analytical methods will be developed to allow the student to better visualize the reservoir, its contents, and its potential for production. Use of the computer as a tool to handle data, create graphs and log traces, and make computations of reservoir parameters is required. Prerequisite: GPGN314. 3 hours lecture; 3 semester hours.

GPGN420. ELECTRICAL AND ELECTROMAGNETIC METHODS. 3.0 Semester Hrs.
Equivalent with GPGN422,
(II) In-depth study of the application of electrical and electromagnetic methods to crustal studies, minerals exploration, oil and gas exploration, and groundwater. Laboratory work with mathematical models coupled with field work over areas of known geology. Prerequisite: GPGN314. 3 hours lecture; 3 semester hours.

GPGN432. FORMATION EVALUATION. 4.0 Semester Hrs.
(II) The basics of core analysis and the principles of all common borehole instruments are reviewed. The course teaches interpretation methods that combine the measurements of various borehole instruments to determine rock properties such as porosity, permeability, hydrocarbon saturation, water salinity, ore grade and ash content. The impact of these parameters on reserve estimates of hydrocarbon reservoirs and mineral accumulations is demonstrated. Geophysical topics such as vertical seismic profiling, single well and cross-well seismic are emphasized in this course, while formation testing, and cased hole logging are covered in GPGN419/PEGN419 presented in the fall. The laboratory provides on-line course material and hands-on computer log evaluation exercises. Only one of the two courses GPGN432 and GPGN419/ PEGN419 can be taken for credit. Prerequisites: MATH225, MATH348 or PHGN311. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN435. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.
(I) This course develops the principles of geophysical computing in the context of simulating and validating numerical solutions to the types of partial differential equations commonly found in geophysical investigations (e.g., potential fields, heat flow/diffusion, seismic wave propagation). Students are introduced to architecture of modern computing systems and learn how algorithms can be developed to leverage this architecture to efficiently generate numerical solutions to multidimensional geophysical problems using parallel computing methods. Prerequisite: CSCI250. 2 hours lecture; 3 hours lab; 3 semester hours.

GPGN438. GEOPHYSICS PROJECT DESIGN. 3.0 Semester Hrs.
(II) (WI) Complementary design course for geophysics restricted elective course(s). Application of engineering design principles to geophysics through advanced work, individual in character, leading to an engineering report or senior thesis and oral presentation thereof. Choice of design project is to be arranged between student and individual faculty member who will serve as an advisor, subject to department head approval. Prerequisites: GPGN314, GPGN329, GPGN404. 1 hour lecture; 6 hours lab; 3 semester hours.

GPGN455. EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.
Equivalent with GPGN555,
(I) Earthquakes are amongst the most significant natural hazards faced by mankind, with millions of fatalities forecast this century. They are also our most accessible source of information on Earth's structure, rheology and tectonics, which are what ultimately govern the distribution of its natural resources. This course provides an overview of how earthquake seismology, complemented by geodesy and tectonic geomorphology, can be used to determine earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; mitigate against seismic hazards; illuminate large- and fine-scale features of Earth?s interior using earthquake data. Students will also cover the recent developments in 3D numerical earthquake source and wave propagation modelling as well as common & modern seismic data formats and processing/visualization tools and techniques used in earthquake seismology. Prerequisites: PHGN200, GPGN461, GPGN229. 3 hours lecture; 3 semester hours.

GPGN458. SEISMIC INTERPRETATION. 3.0 Semester Hrs.
(II) This course will give the participants a unique hands-on experience in seismic interpretation working with several sets of field data and industry standard interpretation software. The course will provide valuable knowledge and information in professional career development. The course involves lectures and labs on seismic interpretation on data sets from a variety of petroleum provinces from around the world. Potential projects for interpretation can be from Gulf of Mexico, North Sea and US land and can have time-lapse and multi-component data types. The class is based on completion and presentation of assignments, exams and final project. Final project will be presentation of the prospect as developed by a group of students. 2 hours lecture; 3 hours lab; 3 semester hours.

GPGN461. SEISMIC DATA PROCESSING. 4.0 Semester Hrs.
Equivalent with GPGN452,
(I) This course covers the basic processing steps required to create images of the earth using 2D and 3D reflection seismic data. Topics include data organization and domains, signal processing to enhance temporal and spatial resolution, identification and suppression of incoherent and coherent noise, velocity analysis, near-surface statics, datuming, normal- and dip-moveout corrections, common-midpoint stacking, principles and methods used for poststack and prestack time and depth imaging, migration velocity analysis and post-imaging enhancement techniques. Realistic synthetic examples and field data sets are extensively used throughout the course. A three-hour lab introduces the student to hands-on data processing using Seismic Unix software package. The final exam consists of processing a 2D seismic line with oral presentation of the results. Prerequisites: GPGN404, GPGN329, GPGN314. 3 hours lecture; 3 hours lab; 4 semester hours.

GPGN470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
(I) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. 3 hours lecture; 3 semester hours.

GPGN471. GEODYNAMICS AND GEOLOGY. 2.0 Semester Hrs.
(I) Earth?s evolving internal dynamics and properties have controlled time-varying crustal geologic processes and their products. All terrestrial planets fractionated synchronously with accretion, but only Earth continued strongly active. Much geology, from ancient granite and greenstone to recently enabled plate-tectonics, will be illustrated in the context of coevolving deep and shallow processes. Integration of geophysics, geology, and planetology will allow evaluation of popular and alternative explanations, but the sum will be contrarian, not conventional. Math and specialist vocabularies will be minimized. PREREQUISITES: CHGN121, PHGN100, PHGN200, and GEGN101. 2 lecture hours, 2 semester hours.

GPGN474. HYDROGEOPHYSICS. 3.0 Semester Hrs.
(II) Application of geophysical methods to problems in hydrology. The course will consider both groundwater and surface water problems from the micro to basin scale. Topics may include characterizing groundwater surface water interaction, critical zone evaluation and weathering processes, snow and ice as a water resource, large scale imaging of aquifer systems, in situ estimation of aquifer parameters, evaluation of groundwater resources, delineation of thermal and chemical pollution of groundwater, and mapping of saltware intrusion. Readings and discussions will touch on social and political issues surrounding water use and the critical role that physical characterization plays in understanding water resources. Prerequisite: GPGN314. 2 hours lecture; 3 hours lab; 3 semester hours.

GPGN475. PLANETARY GEOPHYSICS. 3.0 Semester Hrs.
(I) Of the solid planets and moons in our Solar System, no two bodies are exactly alike. This class will provide an overview of the observed properties of the planets and moons, cover the basic physical processes that govern their evolution, and then investigate how the planets differ and why. The overarching goals are to develop a quantitative understanding of the processes that drive the evolution of planetary surfaces and interiors, and to develop a deeper understanding of the Earth by placing it in the broader context of the Solar System. Prerequisites: PHGN100, MATH225, and GEGN205 or GEOL410. Senior or graduate standing recommended. 3 hours lecture; 3 semester hours.

GPGN486. GEOPHYSICS FIELD CAMP. 4.0 Semester Hrs.
(S) (WI) Introduction to geological and geophysical field methods. The program includes exercises in geological surveying, stratigraphic section measurements, geological mapping, and interpretation of geological observations. Students conduct geophysical surveys related to the acquisition of seismic, gravity, magnetic, and electrical observations. Students participate in designing the appropriate geophysical surveys, acquiring the observations, reducing the observations, and interpreting these observations in the context of the geological model defined from the geological surveys. Prerequisites: GPGN268, GPGN314, GPGN329, GPGN335, GEGN203 or GEGN204, GEGN205. 12 hours lab; 4 semester hours.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN498. SPECIAL TOPICS IN GEOPHYSICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

GPGN499. GEOPHYSICAL INVESTIGATION. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

GPGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

GPGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

GPGN507. NEAR-SURFACE FIELD METHODS. 3.0 Semester Hrs.
(I) Students design and implement data acquisition programs for all forms of near-surface geophysical surveys. The result of each survey is then modeled and discussed in the context of field design methods. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, even years.

GPGN509. PHYSICAL AND CHEMICAL PROPERTIES AND PROCESSES IN ROCK, SOILS, AND FLUIDS. 3.0 Semester Hrs.
(I) Physical and chemical properties and processes that are measurable with geophysical instruments are studied, including methods of measurement, interrelationships between properties, coupled processes, and processes which modify properties in pure phase minerals and fluids, and in mineral mixtures (rocks and soils). Investigation of implications for petroleum development, minerals extraction, groundwater exploration, and environmental remediation. Prerequisite: none. 3 hours lecture, 3 semester hours.

GPGN511. ADVANCED GRAVITY AND MAGNETIC EXPLORATION. 4.0 Semester Hrs.
(I) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing, and interpreting gravity and magnetic data, methods for the solution of two- and three-dimensional potential field problems, Fourier transforms as applied to gravity and magnetics, the geologic implications of filtering gravity and magnetic data, equivalent distributions, harmonic functions, inversions. Prerequisite: GPGN411. 3 hours lecture, 3 hours lab and field; 4 semester hours.

GPGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.
(II) A detailed review of well logging and other formation evaluation methods will be presented, with the emphasis on the imaging and characterization of hydrocarbon reservoirs. Advanced logging tools such as array induction, dipole sonic, and imaging tools will be discussed. The second half of the course will offer in parallel sessions: for geologists and petroleum engineers on subjects such as pulsed neutron logging, nuclear magnetic resonance, production logging, and formation testing; for geophysicists on vertical seismic profiling, cross well acoustics and electro-magnetic surveys. Prerequisite: GPGN419/PEGN419. 3 hours lecture; 3 semester hours.

GPGN520. ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.
(I) Electromagnetic theory. Instrumentation. Survey planning. Processing of data. Geologic interpretations. Methods and limitations of interpretation. Prerequisite: GPGN302 and GPGN303. 3 hours lecture, 3 hours lab; 4 semester hours. Offered fall semester, odd years.

GPGN521. ADVANCED ELECTRICAL AND ELECTROMAGNETIC EXPLORATION. 4.0 Semester Hrs.
(II) Field or laboratory projects of interest to class members; topics for lecture and laboratory selected from the following: new methods for acquiring, processing and interpreting electrical and electromagnetic data, methods for the solution of two- and three-dimensional EM problems, physical modeling, integrated inversions. Prerequisite: GPGN420 or GPGN520. 3 hours lecture, 3 hours lab; 4 semester hours. Offered spring semester, even years.

GPGN530. APPLIED GEOPHYSICS. 3.0 Semester Hrs.
(II) Introduction to geophysical techniques used in a variety of industries (mining, petroleum, environmental and engineering) in exploring for new deposits, site design, etc. The methods studied include gravity, magnetic, electrical, seismic, radiometric and borehole techniques. Emphasis on techniques and their applications are tailored to student interests. The course, intended for non-geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique so that non-specialists can more effectively evaluate the results of geophysical investigations. Prerequisites: PHGN100, PHGN200, MATH111, GEGN401. 3 hours lecture; 3 semester hours.

GPGN533. GEOPHYSICAL DATA INTEGRATION & GEOSTATISTICS. 3.0 Semester Hrs.
(I) Students will learn the fundamentals of and explore opportunities for further development of geostatistical data integration techniques for subsurface earth modeling. The class will build on probability theory, spatial correlations and geostatistics algorithms for combing data of diverse support and resolution into subsurface models. The emphasis of the material will be on stochastic methods for combining quantitative and qualitative data into many equi-probable realizations. Activities include computer modeling, written exercises, oral team presentations, and a semester project with opportunity to enhance student?s respective research projects. Also, we will read, discuss and implement current research articles the in literature to encourage implementation of state-of-the-art practices and/or highlighting current opportunities for research. 3 hours lecture; 3 semester hours.

GPGN535. GEOPHYSICAL COMPUTING. 3.0 Semester Hrs.
(I) A survey of computer programming skills most relevant to geophysical data processing, visualization and analysis. Skills enhanced include effective use of multiple programming languages, data structures, multicore systems, and computer memory hierarchies. Problems addressed include multidimensional geophysical image processing, geophysical data acquired at scattered locations, finite-difference approximations to partial differential equations, and other computational problems encountered in research by students. Prerequisites: Experience programming in Java, C, C++ or Fortran. 3 hours lecture, 3 credit hours.

GPGN540. MINING GEOPHYSICS. 3.0 Semester Hrs.
(I) Introduction to gravity, magnetic, electric, radiometric and borehole techniques used primarily by the mining industry in exploring for new deposits but also applied extensively to petroleum, environmental and engineering problems. The course, intended for graduate geophysics students, will emphasize the theoretical basis for each technique, the instrumentation used and data collection, processing and interpretation procedures specific to each technique. Prerequisites: GPGN221, GPGN322, MATH111, MATH112, MATH213. 3 hours lecture; 3 semester hours.

GPGN551. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
(I, II) Students will probe a range of current methodologies and issues in seismic data processing, and discuss their ongoing and planned research projects. Topic areas include: Statics estimation and compensation, deconvolution, multiple suppression, wavelet estimation, imaging and inversion, anisotropic velocity and amplitude analysis, seismic interferometry, attenuation and dispersion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Every student registers for GPGN551 in only the first semester in residence and receives a grade of PRG. The grade is changed to a letter grade after the student's presentation of thesis research. Prerequisite: none. 1 hour seminar; 1 semester hour.

GPGN552. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.
(I) Introduction to basic principles of elasticity including Hooke?s law, equation of motion, representation theorems, and reciprocity. Representation of seismic sources, seismic moment tensor, radiation from point sources in homogeneous isotropic media. Boundary conditions, reflection/transmission coefficients of plane waves, plane-wave propagation in stratified media. Basics of wave propagation in attenuative media, brief description of seismic modeling methods. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN553. INTRODUCTION TO SEISMOLOGY. 3.0 Semester Hrs.
(II) This course is focused on the physics of wave phenomena and the importance of wave-theory results in exploration and earthquake seismology. Includes reflection and transmission problems for spherical waves, methods of steepest descent and stationary phase, point-source radiation in layered isotropic media, surface and non-geometrical waves. Discussion of seismic modeling methods, fundamentals of wave propagation in anisotropic and attenuative media. Prerequisite: GPGN552. 3 hours lecture; 3 semester hours. Offered spring semester, even years.

GPGN555. INTRODUCTION TO EARTHQUAKE SEISMOLOGY. 3.0 Semester Hrs.
Equivalent with GPGN455,
(II) Earthquakes are amongst the most significant natural hazards faced by mankind, with millions of fatalities forecast this century. They are also our most accessible source of information on Earth's structure, rheology and tectonics, which are what ultimately govern the distribution of its natural resources. This course provides an overview of how earthquake seismology, complemented by geodesy and tectonic geomorphology, can be used to determine Earth structure, earthquake locations, depths and mechanisms; understand Earth's tectonics and rheology; establish long-term earthquake histories and forecast future recurrence; and mitigate against seismic hazards. GPGN555 differs from GPGN455 in that the assignments are approximately 20% longer and encompass more challenging questions. GPGN555 is the appropriate course for graduate students and for undergraduates who expect to go on to study earthquake seismology at graduate school. Prerequisites: GPGN320. 3 hours lecture; 3 semester hours.

GPGN558. SEISMIC DATA INTERPRETATION. 3.0 Semester Hrs.
(II) Practical interpretation of seismic data used in exploration for hydro carbons. Integration with other sources of geological and geophysical information. Prerequisite: GPGN461, GEOL501 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours.

GPGN561. SEISMIC DATA PROCESSING I. 3.0 Semester Hrs.
(I) Introduction to basic principles underlying the processing of seismic data for suppression of various types of noise. Includes the rationale for and methods for implementing different forms of gain to data, and the use of various forms of stacking for noise suppression, such as diversity stacking of Vibroseis data, normal-moveout correction and common-midpoint stacking, optimum-weight stacking, beam steering and the stack array. Also discussed are continuous and discrete oneand two-dimensional data filtering, including Vibroseis correlation, spectral whitening, moveout filtering, data interpolation, slant stacking, and the continuous and discrete Radon transform for enhancing data resolution and suppression of multiples and other forms of coherent noise. Prerequisite: GPGN461. 3 hours lecture; 3 semester hours.

GPGN562. SEISMIC DATA PROCESSING II. 3.0 Semester Hrs.
(II) The student will gain understanding of applications of deterministic and statistical deconvolution for wavelet shaping, wavelet compression, and multiple suppression. Both reflection-based and refraction-based statistics estimation and correction for 2-D and 3-D seismic data will be covered, with some attention to problems where subsurface structure is complex. Also for areas of complex subsurface structure, students will be introduced to analytic and interactive methods of velocity estimation. Where the near-surface is complex, poststack and prestack imaging methods, such as layer replacement are introduced to derive dynamic corrections to reflection data. Also discussed are special problems related to the processing of multi-component seismic data for enhancement of shearwave information, and those related to processing of vertical seismic profile data for separation of upgoing and downgoing P- and S-wave arrivals. Prerequisite: GPGN461 and GPGN561. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.
(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

GPGN574. GROUNDWATER GEOPHYSICS. 4.0 Semester Hrs.
(II) Description of world groundwater aquifers. Effects of water saturation on the physical properties of rocks. Use of geophysical methods in the exploration, development and production of groundwater. Field demonstrations of the application of the geophysical methods in the solution of some groundwater problems. Prerequisite: none. 3 hours lecture, 3 hours lab; 4 semester hours.

GPGN575. PLANETARY GEOPHYSICS. 3.0 Semester Hrs.
Equivalent with GPGN475,
(I) Of the solid planets and moons in our Solar System, no two bodies are exactly alike. This class will provide an overview of the observed properties of the planets and moons, cover the basic physical processes that govern their evolution, and then investigate how the planets differ and why. The overarching goals are to develop a quantitative understanding of the processes that drive the evolution of planetary surfaces and interiors, and to develop a deeper understanding of the Earth by placing it in the broader context of the Solar System. Prerequisites: Graduate standing. 3 hours lecture; 3 semester hours.

GPGN576. SPECIAL TOPICS IN THE PLANETARY SCIENCES. 1.0 Semester Hr.
(I, II) Students will read and discuss papers on a particular topic in the planetary sciences. The choice of topic will change each semester. The emphasis is on key topics related to the current state and evolution of the solid planets and moons in our solar system. Readings will include both seminal papers and current research on the topic. Students will take turns presenting summaries of the papers and leading the ensuing discussion. Prerequisites: Graduate standing, or senior standing. 1 hour lecture; 1 semester hour. Repeatable for credit.

GPGN581. GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Students must complete one individual presentation during the graduate program, at an approved public venue, before degree is granted. Every thesis-based MS student in Geophysics and Geophysical Engineering registers each semester in residence in the program and receive 0.0 credit hours until the last semester in residence. For the last semester, 1.0 credit hours and a grade of PRG are awarded with satisfactory attendance and successful completion of individual presentation requirement. 1 hour seminar; 0 or 1 semester hours.

GPGN598. SPECIAL TOPICS IN GEOPHYSICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN599. GEOPHYSICAL INVESTIGATIONS MS. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN605. INVERSION THEORY. 3.0 Semester Hrs.
(II) Introductory course in inverting geophysical observations for inferring earth structure and processes. Techniques discussed include: Monte-Carlo procedures, Marquardt-Levenburg optimization, and generalized linear inversion. In addition, aspects of probability theory, data and model resolution, uniqueness considerations, and the use of a priori constraints are presented. Students are required to apply the inversion methods described to a problem of their choice and present the results as an oral and written report. Prerequisite: MATH225 and knowledge of a scientific programming language. 3 hours lecture; 3 semester hours.

GPGN651. ADVANCED SEISMOLOGY. 3.0 Semester Hrs.
(I) In-depth discussion of wave propagation and seismic processing for anisotropic, heterogeneous media. Topics include influence of anisotropy on plane-wave velocities and polarizations, traveltime analysis for transversely isotropic models, anisotropic velocity-analysis and imaging methods, point-source radiation and Green?s function in anisotropic media, inversion and processing of multicomponent seismic data, shear-wave splitting, and basics of seismic fracture characterization. Prerequisites: GPGN552 and GPGN553. 3 hours lecture; 3 semester hours.

GPGN658. SEISMIC WAVEFIELD IMAGING. 3.0 Semester Hrs.
(I) Seismic imaging is the process that converts seismograms, each recorded as a function of time, to an image of the earth's subsurface, which is a function of depth below the surface. The course emphasizes imaging applications developed from first principles (elastodynamics relations) to practical methods applicable to seismic wavefield data. Techniques discussed include reverse-time migration and migration by wavefield extrapolation, angle-domain imaging, migration velocity analysis and analysis of angle-dependent reflectivity. Students do independent term projects presented at the end of the term, under the supervision of a faculty member or guest lecturer. Prerequisite: none. 3 hours lecture; 3 semester hours.

GPGN660. MATHEMATICS OF SEISMIC IMAGING AND MIGRATION. 3.0 Semester Hrs.
(II) During the past 40 years geophysicists have developed many techniques (known collectively as ?migration?) for imaging geologic structures deep within the Earth?s subsurface. Beyond merely imaging strata, migration can provide information about important physical properties of rocks, necessary for the subsequent drilling and development of oil- and gas-bearing formations within the Earth. In this course the student will be introduced to the mathematical theory underlying seismic migration, in the context of ?inverse scattering imaging theory.? The course is heavily oriented toward problem solving. 3 hours lecture; 3 semester hours. Offered spring semester, odd years.

GPGN681. GRADUATE SEMINAR - PHD. 1.0 Semester Hr.
(I, II) Attendance at scheduled weekly Heiland Distinguished Lectures during each semester of enrollment. Students must complete one individual presentation at an approved, offcampus conference before degree is granted. Every PhD student in Geophysics and Geophysical Engineering registers each semester in residence in the program and receive 0.0 credit hours until the last semester in residence. For the last semester, 1.0 credit hours and a grade of PRG are awarded with satisfactory attendance and successful completion of individual presentation requirement. 1 hour seminar; 1 semester hour.

GPGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

GPGN699. GEOPHYSICAL INVESTIGATION-PHD. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

GPGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

HONORS (HNRS)

HNRS105. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES I. 3.5 Semester Hrs.
(I) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. In addition to developing foundational skills in engineering design and problem-solving, students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS 115 to meet degree requirements. If students drop either of these courses, they must take both LAIS100 and EPIC151 or their equivalents in order to graduate. 3 hours lecture; 1.5 hours lab; 3.5 semester hours.

HNRS115. INNOVATION AND DISCOVERY IN ENGINEERING, ARTS, AND SCIENCES II. 3.5 Semester Hrs.
(II) (WI) "Innovation and Discovery in Engineering, Arts, and Sciences" (IDEAS) applies honors pedagogies in a multidisciplinary, integrated environment that highlights the seamless boundaries between science and engineering, design, ethics, and the arts as a path toward making value-informed technical decisions. Students examine place, identity, citizenship, and community in various contexts as they learn what it means to be an engaged and mindful citizen and professional. IDEAS poses ethical problems and hands-on design challenges from a multitude of lenses. It incorporates experiential learning, team-based projects, and seminar discussions to encourage students to think both critically and creatively about their world. Students must pass both HNRS105 and HNRS115 to meet degree requirements. If students drop either of these courses, they must take both LAIS100 and EPIC151 or their equivalents in order to graduate. Prerequisites: HNRS105. 3 hours lecture; 1.5 hours lab; 3.5 semester hours.

HNRS198. SPECIAL TOPICS. 6.0 Semester Hrs.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS199. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS298. SPECIAL TOPICS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS305. EXPLORATIONS IN MODERN AMERICA. 3.0 Semester Hrs.
(I, II) (WI) Honors core course that develops student skills in reading, writing, critical thinking, and oral communication. skills through the exploration of selected topics related to the social, cultural, and political ideas and events that have shaped the development of the modern United States and its role in the world. Prerequisite: Admission to the Program and HASS100. 3 lecture hours, 3 credit hours.

HNRS315. EXPLORATIONS IN THE MODERN WORLD. 3.0 Semester Hrs.
(I, II) (WI) Honors core course that develops student writing skills and critical thinking abilities through the exploration of selected topics related to the social, cultural, and political ideas and developments that have shaped the modern world. Prerequisite: Admission to the Program and HASS100. 3 lecture hours, 3 credit hours.

HNRS398. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HNRS405. MCBRIDE PRACTICUM. 1-3 Semester Hr.
(I, II) (WI) With approval of the Program, a McBride student may enroll in an individualized study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. This option may be used to pursue an approved foreign study program, service learning program, international internship, undergraduate research project, or other authorized experiential learning program of study. Students must also prepare a faculty-guided major research paper that integrates the experience with the goals, objectives, and focus of the Honors Program in Public Affairs. 1-3 semester hours. Repeatable up to 6 hours.

HNRS425. EXPLORATIONS IN POLITICS, POLICY, AND LEADERSHIP. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to policy, politics, and/or leadership through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in The Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS430. EXPLORATIONS IN IDEAS, ETHICS, AND RELIGION. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to ideas, ethics, and/or religion through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS435. EXPLORATIONS IN CULTURE, SOCIETY, AND CREATIVE ARTS. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to culture, society, and/or the creative arts through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS440. EXPLORATIONS IN INTERNATIONAL STUDIES & GLOBAL AFFAIRS. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to international studies and/or global affairs through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS445. EXPLORATIONS IN SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to the relationships between science, technology, and society through case studies, readings, research, and writing. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS450. EXPLORATIONS IN EARTH, ENERGY, AND ENVIRONMENT. 3.0 Semester Hrs.
(I, II) (WI) Study of selected topics related to earth, energy, and/or the environment through case studies, readings, research, and writing. This course may focus on the human dimensions or broader impacts of science, technology, engineering, or mathematics. Prerequisites: HNRS305: Explorations in Modern America and HNRS315: Explorations in the Modern World. Repeatable for credit up to a maximum of 6 hours. 3 lecture hours, 3 credit hours.

HNRS476. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.
(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student?s learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: none. 2 hours lecture; 3-4 hours lab; 3.0 semester hours.

HNRS498. SPECIAL TOPICS IN THE MCBRIDE HONORS PROGRAM IN PUBLIC AFFAIRS. 1-6 Semester Hr.
A Special Topics course will be a pilot course in the McBride curriculum or will be offered as an enhancement to regularly-scheduled McBride seminars. Special Topics courses in the McBride curriculum will not be offered more than twice. Variable credit: 1 - 6 semester hours. Repeatable for credit under different titles.

HNRS499. INDEPENDENT STUDY. 1-6 Semester Hr.
Under special circumstances, a McBride student may use this course number to register for an independent study project which substitutes for or enhances the regularly-scheduled McBride curriculum seminars. Variable credit: 1 - 6 semester hours. Repeatable for credit.

HUMANITIES, ARTS, AND SOCIAL SCIENCES (HASS)

HASS100. NATURE AND HUMAN VALUES. 4.0 Semester Hrs.
Equivalent with LAIS100,
Nature and Human Values will focus on diverse views and critical questions concerning traditional and contemporary issues linking the quality of human life and Nature, and their interdependence. The course will examine various disciplinary and interdisciplinary approaches regarding two major questions: 1) How has Nature affected the quality of human life and the formulation of human values and ethics? (2) How have human actions, values, and ethics affected Nature? These issues will use cases and examples taken from across time and cultures. Themes will include but are not limited to population, natural resources, stewardship of the Earth, and the future of human society. This is a writing-intensive course that will provide instruction and practice in expository writing, using the disciplines and perspectives of the Humanities and Social Sciences. 4 hours lecture/seminar; 4 semester hours.

HASS198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS200. GLOBAL STUDIES. 3.0 Semester Hrs.
Equivalent with LAIS200,SYGN200,
(I, II, S) Part of the Mines core curriculum, following the first-year requirement of HASS 100 (Nature and Human Values). Modern scientists and engineers operate in an increasingly interconnected world. This course is designed to enhance student capacity to understand, appreciate, and critically analyze the global contexts in which they will live and work. Course material examines the modern world through specific thematic lenses, with an emphasis on the major patterns of cultural, political, and/or environmental change. Students will develop original analysis through comparative empirical research on diverse societies and regions, and will communicate this analysis orally and in writing. Prerequisite: HASS100. 3 hours lecture; 3 semester hours.

HASS201. WORKSHOP FOUNDATIONS: THE ART AND CRAFT OF CREATIVE WRITING. 3.0 Semester Hrs.
Equivalent with LAIS201,
(I, II, S) (WI) This course examines the major patterns of modern and contemporary written forms. Topics analyzed include poetics, prose and creative nonfiction, and the personal or lyric essay. Poetics will focus on writing from imagism to modernism to beat and hippy writing, up to contemporary and postmodern poetry. Prose writing will examine the development of the shorts story from inception to contemporary approaches. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars, readings, workshops, and in-class discussion and activities. Prerequisites: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS202. TECHNICAL COMMUNICATION. 3.0 Semester Hrs.
(I) Technical Communication introduces students to the written and oral communication of technical information, and prepares students for effective professional communication. The course covers workplace writing, such as memos, proposals, and reports, visual communication, best practices for layout and design, ethical practices in the workplace, multimodal communication technologies, and oral presentations. 3 hours lecture; 3 semester hours.

HASS220. INTRODUCTION TO PHILOSOPHY. 3.0 Semester Hrs.
Equivalent with LAIS220,
A general introduction to philosophy that explores historical and analytic traditions. Historical exploration may compare and contrast ancient and modern, rationalist and empiricist, European and Asian approaches to philosophy. Analytic exploration may consider such basic problems as the distinction between illusion and reality, the one and the many, the structure of knowledge, the existence of God, the nature of mind or self. Prerequisite: HASS 100. Corequisite: HASS 200. 3 hours lecture; 3 credit hours.

HASS221. INTRODUCTION TO RELIGIONS. 3.0 Semester Hrs.
Equivalent with LAIS221,
This course has two focuses. We will look at selected religions emphasizing their popular, institutional, and contemplative forms; these will be four or five of the most common religions: Hinduism, Buddhism, Judaism, Christianity, and/or Islam. The second point of the course focuses on how the Humanities and Social Sciences work. We will use methods from various disciplines to study religion-history of religions and religious thought, sociology, anthropology and ethnography, art history, study of myth, philosophy, analysis of religious texts and artifacts (both contemporary and historical), analysis of material culture and the role it plays in religion, and other disciplines and methodologies. We will look at the question of objectivity; is it possible to be objective? We will approach this methodological question using the concept ?standpoint.? For selected readings, films, and your own writings, we will analyze what the ?standpoint? is. Prerequisite: HASS 100. Corequisite: HASS 200. 3 hours lecture; 3 semester hours.

HASS226. BEGINNING CLASS PIANO AND FUNDAMENTALS OF MUSIC. 3.0 Semester Hrs.
Equivalent with LAIS226,
(I, II, S) HASS 226 is a beginning keyboard class. Students will learn to read music, develop fundamental keyboard skills, grasp basic music theory and history concepts, and understand the communal nature of music through ensemble preparation and public performance. Assessment will be based on class participation, written exams, student reflection papers, written and aural homework assignments, and public performances in class. The course will be a recommended, but not required, prerequisite for HASS 326 (Music Theory) and HASS 328 (Basic Music Composition and Arranging). Prerequisite: HASS100. Corequisite: HASS 200. 3 hours lecture; 3 semester hours.

HASS286. GLOBAL POLITICS & SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS286,
(I, II, S) This is a beginning- level course intended to familiarize students with the study of politics across societies. The method is comparative in that it approaches the task of studying the world's different political systems by contrasting and comparing them along different dimensions, and by seeking generalizations about them. The class focuses on cases, topics, and methodologies in American and comparative politics. The course is part of the Global Politics & Society Minor. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS298. SPECIAL TOPICS. 6.0 Semester Hrs.
Equivalent with LAIS298B,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS298. SPECIAL TOPICS. 6.0 Semester Hrs.
Equivalent with LAIS298C,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS299B,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS299C,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS299. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS299D,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS300. CREATIVE WRITING: FICTION. 3.0 Semester Hrs.
Equivalent with LAIS300,
Students will write weekly exercises and read their work for the pleasure and edification of the class. The midterm in this course will be the production of a short story. The final will consist of a completed, revised short story. The best of these works may be printed in a future collection. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS301. CREATIVE WRITING: POETRY I. 3.0 Semester Hrs.
Equivalent with LAIS301,
This course focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and stimulate the development of the student?s craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students ?try on? various styles and contexts in order to develop their own voice. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS305. AMERICAN LITERATURE: COLONIAL PERIOD TO THE PRESENT. 3.0 Semester Hrs.
Equivalent with LAIS305,
This course offers an overview of American literature from the colonial period to the present. The texts of the class provide a context for examining the traditions that shape the American nation as a physical, cultural and historical space. As we read, we will focus on the relationships between community, landscape, history, and language in the American imagination. We will concentrate specifically on conceptions of the nation and national identity in relation to race, gender, and class difference. Authors may include: Rowlandson, Brown, Apess, Hawthorne, Douglass, Melville, Whitman, James, Stein, Eliot, Hemingway, Silko, and Auster. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS307. EXPLORATIONS IN COMPARATIVE LITERATURE. 3.0 Semester Hrs.
Equivalent with LAIS307,
This course examines major figures and themes in the modern literatures of Africa, the Caribbean, and Latin America. Reading, discussion and writing will focus on fiction and poetry representing Francophone, Arabic, and Hispanophone traditions within these world regions. Engaging these texts will foster understanding of some of the pivotal philosophical, political, and aesthetic debates that have informed cultural practices in diverse colonial territories and nation-states. Thematic and stylistic concerns will include imperialism, nationalism, existentialism, Orientalism, negritude, and social and magical realisms. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS309. LITERATURE AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS309,
Before the emergence of sociology as a distinct field of study, literary artists had long been investigating the seemingly infinite complexity of human societies, seeking to comprehend the forces shaping collective identities, socio-cultural transformations, technological innovations, and political conflicts. Designed to enrich recognition and understanding of the complex interplay of artistic creativity and social inquiry over time, this course compares influential literary and social-scientific responses to the Enlightenment, the Industrial Revolution, and other dynamic junctures integral to the forging of "modernity" and the volatile world we inhabit today. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS315. MUSICAL TRADITIONS OF THE WESTERN WORLD. 3.0 Semester Hrs.
Equivalent with LAIS315,
An introduction to music of the Western world from its beginnings to the present. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS320. ETHICS. 3.0 Semester Hrs.
Equivalent with LAIS320,
A general introduction to ethics that explores its analytic and historical traditions. Reference will commonly be made to one or more significant texts by such moral philosophers as Plato, Aristotle, Augustine, Thomas Aquinas, Kant, John Stuart Mill, and others. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS323. INTRODUCTION TO SCIENCE COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS323,
This course will explore the relationship between science and the public through an examination of science writing and communication on current events. Students will study various forms of science communication, including essays, blogs, news segments, media clips, and radio programs in order to understand the ways in which science is communicated beyond the lab or university and into the public consciousness. Science writing often explores the human condition, reflects on hopes and worries about technology, and informs our collective knowledge about the world. Students will discuss the implications of this kind of communication, analyze breakdowns in communication through case studies, and write for peer and popular audiences, including turning a lab report into a short feature article and writing a science essay. Prerequisite: HASS100. Corequisite HASS200. 3 hours lecture; 3 semester hours.

HASS324. AUDIO/ACOUSTICAL ENGINEERING AND SCIENCE. 3.0 Semester Hrs.
Equivalent with LAIS324,
(I) Audio/acoustical engineering and science teaches concepts surrounding the production, transmission, manipulation and reception of audible sound. These factors play a role in many diverse areas such as the design of modern music technology products, recording studios and loudspeakers, civil engineering and building design, and industrial safety. This course will explore and concepts of this field and the physics/mechanics that are involved, as well as aesthetic impacts related to the subject matter. Discussion of human anatomy and psycho acoustic phenomena are also presented. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS325. CULTURAL ANTHROPOLOGY. 3.0 Semester Hrs.
Equivalent with LAIS325,
A study of the social behavior and cultural devel opment of humans. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS326. MUSIC THEORY. 3.0 Semester Hrs.
Equivalent with LAIS326,
(I) The course begins with the fundamentals of music theory and moves into more complex applications. Music of the common practice period (18th century) and beyond is considered. Aural and visual recognition of harmonic material is emphasized. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS327. MUSIC TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with LAIS327,
(I, II) An introduction to the physics of music and sound. The history of music technology from wax tubes to synthesizers. Construction of instruments and studio. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS328. BASIC MUSIC COMPOSITION AND ARRANGING. 1.0 Semester Hr.
Equivalent with LAIS328,
(I) This course begins with the fundamentals of music composition and works towards basic vocal and instrumental arrangement skills. Upon completion of this course the student should: 1) Demonstrate basic knowledge of (music) compositional techniques; 2) Demonstrate primary concepts of vocal and instrumental ensemble arrangement; 3) Demonstrate an ability to use notational software and Midi station hardware. Prerequisite: HASS100. Corequisite: HASS200. Repeatable for credit. 1 hour lecture; 1 semester hour.

HASS330. MUSIC TECHNOLOGY CAPSTONE. 3.0 Semester Hrs.
Equivalent with LAIS330,
(II) Project-based course designed to develop practical technological and communication skills for direct application to the music recording. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS337. ASIA: POLITICS & SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS337,
(I, II, S) (WI) A broad survey of the interrelationship between the state and economy in East and Southeast Asia as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics of interstate relationships between the developed North and the developing South. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS339. MIDDLE EAST: POLITICS & SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS339,
(I, II, S) (WI) A broad survey of the interrelationships between the state and market in the Middle East as seen through an examination of critical contemporary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS341. AFRICA: POLITICS & SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS341,
(I, II, S) (WI) A broad survey of the interrelationships between the state and market in Africa as seen through an examination of critical contem porary and historical issues that shape polity, economy, and society. Special emphasis will be given to the dynamics between the developed North and the developing South. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS344. INTERNATIONAL RELATIONS. 3.0 Semester Hrs.
Equivalent with LAIS344,
This course surveys major topics and theories of international relations. Students will evaluate diverse perspectives and examine a variety of topics including war and peace, economic globalization, human rights and international law, international environmental issues, and the role of the US as the current superpower. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS365. HISTORY OF WAR. 3.0 Semester Hrs.
Equivalent with LAIS365,
History of War looks at war primarily as a significant human activity in the history of the Western World since the times of Greece and Rome to the present. The causes, strategies, results, and costs of various wars will be covered, with considerable focus on important military and political leaders as well as on noted historians and theoreticians. The course is primarily a lecture course with possible group and individual presentations as class size permits. Tests will be both objective and essay types. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS370. HISTORY OF SCIENCE. 3.0 Semester Hrs.
Equivalent with LAIS370,
An introduction to the social history of science, exploring significant people, theories, and social practices in science, with special attention to the histories of physics, chemistry, earth sciences, ecology, and biology. Prerequisite: HASS100. Corequisite HASS200. 3 hours lecture; 3 semester hours.

HASS376. COMMUNITY ENGAGEMENT THROUGH SERVICE LEARNING. 3.0 Semester Hrs.
Equivalent with LAIS376,
(II) Community Engagement through Service Learning combines a traditional classroom environment with an off campus learning experience with a local non-profit or community organization. Students spend 3-4 hours per week serving the organization they choose and meet in class once per week to discuss reading assignments, present research findings, and share experiences and insights about the course material. Instructors may choose to focus on a particular topic or social issue, such as poverty and privilege, or may engage with community issues more broadly. The course focuses on several aspects of a student?s learning, including intra- and interpersonal learning, discovering community, and developing communication skills and critical and interdisciplinary approaches. Course work will focus on critical reading, group discussion and deliberation, oral presentations of research, and writing assignments. Prerequisites: HASS100. Corequisite: HASS200. 2 hours lecture; 3 hours lab; 3 semester hours.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS398B,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS398C,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS398. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS398D,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS399B,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS399C,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS399D,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS399. INDEPENDENT STUDY. 1-6 Semester Hr.
Equivalent with LAIS399E,
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS400. ADVANCED SHORT FICTION WRITING WORKSHOP. 3.0 Semester Hrs.
(II) (WI) This upper-level HASS course examines the major patterns of modern and contemporary written forms of fiction, and asks students to apply what they learn in their own writing. Topics analyzed include: prose and narrative theory, organizational approaches to fiction, plot, character, setting, and all the many aspects of professional creative writing. Critical prose writing by the students will examine the development of the short story from inception to contemporary approaches. Analysis of historical trends and change will also serve as a basis for developing student writing habits and strategies. Over the course of the semester, these subjects will be addressed through seminars, readings, workshops, and in-class discussion and activities. Students will advance their own fiction-writing skills, which will be demonstrated in two new short stories over the course of the semester, and will turn in a final portfolio and critical paper to show their growth. Prerequisites: HASS100, HASS200. Corequisites: HASS300, HASS301, and HASS401. 3 hours seminar; 3 semester hours.

HASS401. CREATIVE WRITING: POETRY II. 3.0 Semester Hrs.
Equivalent with LAIS401,
This course is a continuation of HASS 301 for those interested in developing their poetry writing further. It focuses on reading and writing poetry. Students will learn many different poetic forms to compliment prosody, craft, and technique. Aesthetic preferences will be developed as the class reads, discusses, and models some of the great American poets. Weekly exercises reflect specific poetic tools, encourage the writing of literary poetry, and simulate the development of the student? s craft. The purpose of the course is to experience the literature and its place in a multicultural society, while students ?try on? various styles and contexts in order to develop their own voice. Prerequisite: HASS100, HASS301. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS404. WOMEN, LITERATURE, AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS404,
This reading and writing intensive course examines the role that women writers have played in a range of literary traditions. Far from residing in the margins of key national debates, women writers have actively contributed their voices to demands for social, racial, economic, and artistic equality. We will examine the writing produced by women from a diversity of racial, ethnic, and social backgrounds, as we examine the ways in which women writers respond to the various pressures placed on them as artists and activists. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS406. THE LITERATURE OF WAR AND REMEMBRANCE. 3.0 Semester Hrs.
Equivalent with LAIS406,
In "The Literature of War and Remembrance," students survey poetry, prose, and film ranging from classicial to contemporary war literature. The course considers literary depictions of the individual and society in war and its aftermath. Critical reading and writing skills are demonstrated in creative presentations and analytical essays. Students will investigate war literature and commemorative art inspired by recent world conflicts, and place a contemporary work into the thematic structure of the course. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS407. SCIENCE IN LITERATURE. 3.0 Semester Hrs.
Equivalent with LAIS407,
Science fiction often serves as a cautionary tale that deals with the darker side of humanity's desires in order to find a better understanding of who we are and what we hope to become. This class examines scientific and social progress as it is imagined by some of the greatest authors of the genre. We will examine the current events that may have influenced the writing and position our lens to the scientific and technological breakthroughs, as well as the social, cultural, and political state of the world at the time of our readings. This course focuses on classic science fiction from the late 1800's to the present which may include: Jules Verne, H.G. Wells, Sir Arthur Conan Doyle, Jack Williamson, Isaac Asimov, Robert Heinlein, Alfred Bester, Philip Jose Farmer, Marion Zimmer Bradley, Ray Bradbury, Philip K. Dick, William Gibson, Arthur C. Clarke, Ursula K. LeGuin and Mary Doria Russell, among others. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS408. LIFE STORIES. 3.0 Semester Hrs.
Equivalent with LAIS408,
Using texts by published authors and members of the class, we will explore the pleasures and challenges of creating and interpreting narratives based on "real life." The class will consider critical theories about the relationship between the self and the stories we tell. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS409. SHAKESPEAREAN DRAMA. 3.0 Semester Hrs.
Equivalent with LAIS409,
Shakespeare, the most well known writer in English and perhaps the world, deals with universal themes and the ultimate nature of what it is to be a human being. His plays are staged, filmed, and read around the globe, even after 400 years. This seminar will explore why Shakespeare? s plays and characters have such lasting power and meaning to humanity. The seminar will combine class discussion, lecture, and video. Grades will be based on participation, response essays, and a final essay. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS410. CRITICAL PERSPECTIVES ON 20TH CENTURY LITERATURE. 3.0 Semester Hrs.
Equivalent with LAIS410,
This course introduces students to texts and cultural productions of the 20th Century literature. We will examine a diverse collection of materials, including novels and short stories, poems, plays, films, painting, and sculpture. Science, technology, violence, history, identity, language all come under the careful scrutiny of the authors we will discuss in this course, which may include Conrad, Fanon, Achebe, Eliot, Kafka, Barnes, Camus, Borges, and Marquez, among others. We will also screen films that comment upon the fragility of individual identity in the face of modern technology. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS411. LITERATURES OF THE AFRICAN WORLD. 3.0 Semester Hrs.
Equivalent with LAIS411,
This course examines wide-ranging writers' depictions of collective transformations and conflicts integral to the making and remaking of African and Afro-diasporic communities worldwide. Fiction, poetry, and essays representing diverse linguistic, aesthetic, and philosophical traditions will constitute the bulk of the reading. Alongside their intrinsic expressive values, these texts illuminate religious and popular cultural practices important to social groups throughout much of sub-Saharan Africa, the Caribbean, Latin America, and the United States. Primary socio-historical themes may include the slave trade, plantation cultures, generational consciousness, ethnicity, gender relations, urbanization, and collective violence. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS412. LITERATURE AND THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with LAIS412,
This reading and writing intensive course investigates the human connection to the environment in a broad range of literary materials. Discussions focus on the role of place - of landscape as physical, cultural, moral, historical space - and on the relationship between landscape and community, history, and language in the environmental imagination. Readings include texts that celebrate the natural world, those that indict the careless use of land and resources, and those that predict and depict the consequences of that carelessness. Additionally, we investigate philosophical, legal, and policy frameworks that shape approaches to environmental issues. Prerequisite: HASS100. Corequesite HASS200. 3 hours seminar; 3 semester hours.

HASS415. MASS MEDIA STUDIES. 3.0 Semester Hrs.
Equivalent with LAIS415,
This introduction to mass media studies is designed to help students become more active interpreters of mass media messages, primarily those that emanate from television, radio, the Internet, sound recordings (music), and motions pictures (film, documentary, etc.). Taking a broad rhetorical and sociological perspective, the course examines a range of mass media topics and issues. Students should complete this course with enhanced rhetorical and sociological understandings of how media shapes individuals, societies, and cultures as well as how those groups shape the media. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS416. FILM STUDIES. 3.0 Semester Hrs.
Equivalent with LAIS416,
This course introduces students to the basics of film history, form, and criticism. Students will be exposed to a variety of film forms, including documentary, narrative, and formalist films, and will be encouraged to discuss and write about these forms using critical film language. Students will have an opportunity to work on their own film projects and to conduct research into the relationship between films and their historical, cultural, and ideological origins. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS418. NARRATING THE NATION. 3.0 Semester Hrs.
Equivalent with LAIS418,
The novel, nationalism, and the modern nation-state share the same eighteenth and nineteenth-century roots. Relationships between the works of novelists, local nationalisms, and state politics have, however, always been volatile. These tensions have assumed particularly dramatic expressive and political forms in Latin America and postcolonial South Asia and Africa. This course examines the inspirations, stakes, and ramifications of celebrated novelists' explorations of the conflicted and fragmentary character their own and/or neighboring nationstates. Beyond their intrinsic literary values, these texts illuminate distinctive religious, ritual, and popular cultural practices that have shaped collective imaginings of the nation, as well as oscillations in nationalist sentiment across specific regions and historical junctures. Studies in relevant visual media -films, paintings, and telenovelas - will further our comparative inquiry into the relationships between artistic narrative and critical perspectives on "the nation." Alongside the focal literary and visual texts, the course will address major historians' and social theorists' accounts of the origins, spread, and varied careers of nationalist thought and practice across our modern world. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS419. ENVIRONMENTAL COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS419,
(I, II, S) (WI) This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in environmental communication, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of environmentalism and the natural world are constructed and contested. Students will critically analyze their roles as science and/or technology communicators in the context of environmental issues and will apply their skills to creating communications projects for diverse audiences. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS421. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS421,
A critical examination of environmental ethics and the philosophical theories on which they depend. Topics may include preservation/ conservation, animal welfare, deep ecology, the land ethic, eco-feminism, environmental justice, sustainability, or non-western approaches. This class may also include analyses of select, contemporary environmental issues. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS423. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS423,
This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS425. INTERCULTURAL COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS425,
(I, II) The course examines intercultural communication theory and practice. In particular, the course provides students with a window into how intercultural (mis)communication cases arise, evolve, and are resolved. Students investigate communication cases and issues across a broad range of cultural divides, such as national, ethnic, gender, and social class cultures. Some case studies are situated in engineering and applied science contexts. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS426. SCIENTIFIC CONTROVERSIES. 3.0 Semester Hrs.
Equivalent with LAIS426,
(I, II) Examines national and international, historical and contemporary scientific and engineering controversies. In particular, the course provides students with a window into how scientific controversies arise, evolve, and are resolved both within scientific circles and in the public arena. By exploring case studies of such controversies, students gain a better understanding about how scientific controversies shape and are shaped by communication as well as by public policy. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture, 3 semester hours.

HASS429. REAL WORLD RECORDING/RESEARCH. 3.0 Semester Hrs.
Equivalent with LAIS429,
(WI) This reading and writing-intensive course explores the acoustical, musical, and technical aspects of recording a variety of live ethno-musicological music genres and/or performances, towards the purpose of learning how to research, document and capture the most accurate and authentic recording. Historical research, non-traditional recording techniques; archival documentation, and editing will all be a part of this course. Prerequisites: HASS100 and HASS315 or HASS327. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS431. MORAL PSYCHOLOGY, RELIGION, AND AMERICAN SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS431,
(I, II, S) (WI) This course introduces intersections of moral psychology, religion in American society. Course begins with an understanding of religion in the United States and how religion has influenced foreign affairs throughout history (national security). Course introduces insights from moral psychology to shed light on the political spectrum in American political life. The course then explores how faith-based organizations make decisions on when and how to enter American political life for social change (intrasecurity). Finally, the course explores the connections between religion and terrorism that have seen some rise in the early 21st century (national security). Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS433. SHAKESPEARE AND THE SCIENTIFIC REVOLUTION. 3.0 Semester Hrs.
Equivalent with LAIS433,
(I, II, S) (WI) This course investigates ways in which William Shakespeare, a contemporary of Galileo, reflects in his work scientific theories and discoveries emerging during the Renaissance that transformed long-held world views. Shakespeare presents characters encountering unprecedented challenges interpreting their own relationship to the natural world and the political world, the spiritual world and the New World, the world of arts and the human imagination. Because the Renaissance concept of science is so broad and multi-disciplinary, students will be able to pursue individual interests in their research for this course. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS435. LATIN AMERICAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS435,
A seminar designed to explore the political economy of current and recent past development strategies, models, efforts, and issues in Latin America, one of the most dynamic regions of the world today. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. The role of both the state and the market in development processes will be examined. Topics to be covered will vary as changing realities dictate but will be drawn from such subjects as inequality of income distribution; the role of education and health care; region-markets; the impact of globalization, institution-building, corporate-community-state interfaces, neoliberalism, privatization, democracy, and public policy formulation as it relates to development goals. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS437. ASIAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS437,
This international political economy seminar deals with the historical development of Asia Pacific from agrarian to post-industrial eras; its economic, political, and cultural transformation since World War II, contemporary security issues that both divide and unite the region; and globalization processes that encourage Asia Pacific to forge a single trading bloc. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS439. MIDDLE EAST DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS439,
This internationa political economy seminar analyzes economic, political and social dynamics that affect the progress and direction of states, markets, and peoples of the region. It examines the development of the Middle East from agrarian to post-industrial societies; economic, political and cultural transformations since World War II; contemporary security issues that both divide and unite the region; and the effects of globalization processes on economies and societies in the Middle East. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS441. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS441,
This course provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS442. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.
Equivalent with LAIS442,
Africa possesses abundant natural resources yet suffers civil wars and international conflicts based on access to resource revenues. The course examines the distinctive history of Africa, the impact of the resource curse, mismanagement of government and corruption, and specific cases of unrest and war in Africa. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS446. GLOBALIZATION. 3.0 Semester Hrs.
Equivalent with LAIS446,
This international political economy seminar is an historical and contemporary analysis of globalization processes examined through selected issues of world affairs of political, economic, military, and diplomatic significance. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS448. GLOBAL ENVIRONMENTAL ISSUES. 3.0 Semester Hrs.
Equivalent with LAIS448,
Critical examination of interactions between development and the environment and the human dimensions of global change; social, cpolitical, economic, and cultural responses to the management and preservation of natural resources and ecosystems on a global scale. Exploration of the meaning and implications of ?Stewardship of the Earth? and ?Sustainable Development.? Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS450. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.
Equivalent with LAIS450,
This course will review the existing methodologies and techniques of risk assessment in both country-specific and global environments. It will also seek to design better ways of assessing and evaluating risk factors for business and public diplomacy in the increasingly globalized context of economy and politics wherein the role of the state is being challenged and redefined. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS452. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS452,
(I, II, S) (WI) This course addresses the problem of corruption and its impact on development. Readings are multi disciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or bribe taking might occur. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS453. ETHNIC CONFLICT IN GLOBAL PERSPECTIVE. 3.0 Semester Hrs.
Equivalent with LAIS453,
Many scholars used to believe that with modernization, racial, religious, and cultural antagonisms would weaken as individuals developed more rational outlooks and gave primacy to their economic concerns. Yet, with the waning of global ideological conflict of the left-right nature, conflict based on cultural and "civilization" differences have come to the fore in both developing and developed countries. This course will examine ethnic conflict, broadly conceived, in a variety of contexts. Case studies will include the civil war in Yugoslavia, the LA riots, the antagonism between the Chinese and "indigenous' groups in Southeast, the so-called war between the West and Islam, and ethnic relations in the U.S. We will consider ethnic contention in both institutionalized, political processes, such as the politics of affirmative action, as well as in non-institutionalized, extra-legal settings, such as ethnic riots, pogroms, and genocide. We will end by asking what can be done to mitigate ethnic conflict and what might be the future of ethnic group identification. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS456. POWER AND POLITICS IN EURASIA. 3.0 Semester Hrs.
Equivalent with LAIS456,
This seminar covers the major internal and international issues confronting the fifteen states that once comprised the Soviet Union. After an overview of the USSR and its collapse in 1991, the course explores subsequent economic and security dilemmas facing the "new" nations of Eurasia. Special attention will be paid to oil, natural gas, and other energy sectors in the region. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS458. NATURAL RESOURCES AND DEVELOPMENT. 3.0 Semester Hrs.
(I, II, S) (WI) This course examines the relationship between natural resources and development. It begins by discussing theories of development and how those theories account for specific choices among resource abundant countries. From the theoretical readings, students examine sector specific topics in particular cases. These subjects include oil and natural gas in African and Central Asian countries; hard rock mining in West Africa and East Asia; gemstone mining in Southern and West Africa; contracting in the extractive industries; and corporate social responsibility. Readings are multidisciplinary and draw from policy studies, economics, and political science to provide students an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and development. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS460. GEOPOLITICS OF NATURAL RESOURCES. 3.0 Semester Hrs.
Equivalent with LAIS460,
(I, II, S) (WI) This seminar examines geopolitical competition between great and aspiring powers for influence, control over land and natural resources, critical geo-strategic trade routes, or even infrastructure. Using empirical evidence from case studies, students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of foreign policies, as well as issues of war and peace. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS464. HISTORY OF ENERGY AND THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with LAIS464,
(II) This course examines the major patterns of human energy use and interaction with the natural environment on a global scale from the origins of civilization to the present day. Topics analyzed include the dynamics of historical change in energy and resource use, the ways in which energy and the environment have shaped the development of past societies, cultural perceptions of energy and the environment during different historical eras, and the impact of past human activities on natural systems. Analysis of historical trends will also serve as a basis for discussions related to current issues in energy and the environment. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS467. HISTORY OF EARTH AND ENVIRONMENTAL SCIENCES. 3.0 Semester Hrs.
Equivalent with LAIS467,
This course provides an overview of the history of some of the key sciences that help us understand the world we inhabit: geology, climatology, evolutionary biology, and ecology. As we investigate key scientific discoveries of the modern era, we will also consider the philosophical and cultural impacts of those scientific discoveries. Thus, our reading will include not only original texts by scientists, but also key literary, historical and other texts inspired by those discoveries. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS484. US WATER POLITICS AND POLICY. 3.0 Semester Hrs.
(I) (WI) This interdisciplinary seminar course engages the complexities of contemporary water governance in the United States, with an emphasis on the arid American West, including the state of Colorado. It engages with governance questions such as how we are to share over-allocated water resources, how we are to engage with increasingly unpredictable hydrologic dynamics, and how changes in water science, engineering, and values shape policy and politics and vice versa. The course engages with concepts in ethics, economics, history, law, and policy, and puts them in conversation with dynamics in hydrology, engineering, and social-ecological systems theory. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS485. CONSTITUTIONAL LAW AND POLITICS. 3.0 Semester Hrs.
Equivalent with LAIS485,
This course presents a comprehensive survey of the U.S. Constitution with special attention devoted to the first ten Amendments, also known as the Bill of Rights. Since the Constitution is primarily a legal document, the class will adopt a legal approach to constitutional interpretation. However, as the historical and political context of constitutional interpretation is inseparable from the legal analysis, these areas will also be covered. Significant current developments in constitutional jurisprudence will also be examined. The first part of the course deals with Articles I through III of the Constitution, which specify the division of national governmental power among the executive, legislative, and judicial branches of government. Additionally, the federal nature of the American governmental system, in which governmental authority is apportioned between the national government and the state governments, will be studied. The second part of the course examines the individual rights specifically protected by the amendments to the Constitution, principally the First, Fourth, Fifth, Sixth, Eighth, and Fourteenth Amendments. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS486. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.
Equivalent with LAIS486,
An examination of current issues relating to science and technology policy in the United States and, as appropriate, in other countries. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS487. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS487,
Seminar on environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS488. GLOBAL WATER POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS488,
(II) (WI) This interdisciplinary seminar course analyzes how droughts, floods, water management, global trading system, and climate change affect the hydrological and food systems that are critically important for economic prosperity and political stability. It addresses water policy at scales that range from community level to global governance regimes. It uses relevant analytical perspectives of, for example, psychology, political economy, development studies, and institutional approaches in economic geography to help students understand how certain transboundary water conflicts have emerged, their national and regional implications, and policies and institutions that can be used to resolve them. Prerequisite: HASS100. Corequisite: HASS200. 3 hours seminar; 3 semester hours.

HASS490. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with ENGY490,LAIS490,MNGN490,
(I,II) An interdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development as these affect particular communities and societies. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS491. ENERGY POLITICS. 3.0 Semester Hrs.
(I, II, S) (WI) We will use political science approaches, theories, and methods to investigate the global, regional, state, and local politics of renewable and non-renewable energy, spanning all uses: transportation, heating and cooling, and electricity. We will look at the politics behind energy in a subset of countries to be chosen by the class, such as China, Brazil, India, Austria, Spain, Venezuela, and Germany. We will then focus on energy in Colorado and other US states, conducting primary research on the stakeholders and the relevant political outcomes. We will hear from energy companies, non-governmental organizations, university and research entities, government representatives, legislators, and local activists. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS492. ENERGY AND SECURITY POLICY. 3.0 Semester Hrs.
(I, II, S) (WI) This course applies a social science lens to understanding the intersections between national and international security concerns and energy. We will examine these intersections through a case study approach that includes directed readings, such as books and peer-reviewed journal articles, that incorporate student-led discussions and research projects. By exploring various energy security scenarios, such as restricted access to oil and gas, students will gain a comprehensive understanding of the energy-security nexus and the role governments and policies play in enhancing or limiting security. Prerequisite: HASS100. Corequisite: HASS200. 3 hours lecture; 3 semester hours.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498B,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498C,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498D,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498E,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498F,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498G,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS498. SPECIAL TOPICS. 1-6 Semester Hr.
Equivalent with LAIS498H,
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: HASS100. Corequisite: HASS200. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

HASS499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

HASS521. ENVIRONMENTAL PHILOSOPHY AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS521,
Analyzes environmental ethics and philosophy including the relation of philosophical perspectives to policy decision making. Critically examines often unstated ethical and/or philosophical assumptions about the environment and how these may complicate and occasionally undermine productive policies. Policies that may be considered include environmental protection, economic development, and energy production and use. 3 hours seminar; 3 semester hours.

HASS523. ADVANCED SCIENCE COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS523,
This course will examine historical and contemporary case studies in which science communication (or miscommunication) played key roles in shaping policy outcomes and/or public perceptions. Examples of cases might include the recent controversies over hacked climate science emails, nuclear power plant siting controversies, or discussions of ethics in classic environmental cases, such as the Dioxin pollution case. Students will study, analyze, and write about science communication and policy theories related to scientific uncertainty; the role of the scientist as communicator; and media ethics. Students will also be exposed to a number of strategies for managing their encounters with the media, as well as tools for assessing their communication responsibilities and capacities. 3 hours seminar; 3 semester hours.

HASS525. ENVIRONMENTAL COMMUNICATION. 3.0 Semester Hrs.
Equivalent with LAIS525,
(I, II, S) This course explores the ways that messages about the environment and environmentalism are communicated in the mass media, fine arts, and popular culture. The course will introduce students to key readings in environmental communication, media studies, and cultural studies in order to understand the many ways in which the images, messages, and politics of environmentalism and the natural world are constructed and contested by diverse audiences. Students will critically analyze their roles as science and/or technology communicators in the context of environmental issues, and will apply their skills to creating communications projects for diverse audiences. 3 lecture hours, 3 semester hours.

HASS535. INTERNATIONAL DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS535,
(I, II, S) Explores the political economy of current and recent-historical development strategies, models, efforts, and issues in various world regions. The class will focus on Africa, Asia, Eurasia, Latin America, or the Middle East, depending on the semester. Development is understood to be a nonlinear, complex set of processes involving political, economic, social, cultural, and environmental factors whose ultimate goal is to improve the quality of life for individuals. Students will explore the roles of governments, companies, organizations, and individuals. Exact topics to be covered will vary with current events and the specific region; topics might include income inequality, the role of national and private energy companies, the impact of globalization, the role of development aid, and concepts of good governance. Students may take the course up to three times, covering different regions. 3 hours lecture; 3 semester hours.

HASS541. AFRICAN DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS541,
Provides a broad overview of the political economy of Africa. Its goal is to give students an understanding of the possibilities of African development and the impediments that currently block its economic growth. Despite substantial natural resources, mineral reserves, and human capital, most African countries remain mired in poverty. The struggles that have arisen on the continent have fostered thinking about the curse of natural resources where countries with oil or diamonds are beset with political instability and warfare. Readings give first an introduction to the continent followed by a focus on the specific issues that confront African development today. 3 hours lecture and discussion; 3 semester hours.

HASS542. NATURAL RESOURCES AND WAR IN AFRICA. 3.0 Semester Hrs.
Equivalent with LAIS542,
Examines the relationship between natural resources and wars in Africa. It begins by discussing the complexity of Africa with its several many languages, peoples, and geographic distinctions. Among the most vexing challenges for Africa is the fact that the continent possesses such wealth and yet still struggles with endemic warfare, which is hypothetically caused by greed and competition over resource rents. Readings are multidisciplinary and draw from policy studies, economics, and political science. Students will acquire an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and war in Africa. The course helps students apply the different theories to specific cases and productive sectors. 3 hours lecture and discussion; 3 semester hours.

HASS545. INTERNATIONAL POLITICAL ECONOMY. 3.0 Semester Hrs.
Equivalent with LAIS545,
Introduces students to the field of International Political Economy (IPE) . IPE scholars examine the intersection between economics and politics, with a focus on interactions between states, organizations, and individuals around the world. Students will become familiar with the three main schools of thought on IPE: Realism (mercantilism), Liberalism, and Historical Structuralism (including Marxism and feminism) and will evaluate substantive issues such as the role of international organizations (the World Trade Organization, the World Bank, and the International Monetary Fund), the monetary and trading systems, regional development, international development, foreign aid, debt crises, multinational corporations, and globalization. 3 hours seminar; 3 semester hours.

HASS550. POLITICAL RISK ASSESSMENT. 3.0 Semester Hrs.
Equivalent with LAIS550,
Uses social science analytical tools and readings as well as indices prepared by organizations, such as the World Bank and the International Monetary Fund, to create assessments of the political, social, economic, environmental and security risks that multinational corporations may face as they expand operations around the world. Students will develop detailed political risk reports for specific countries that teams collectively select. Prerequisite: HASS 545 and IPE Minor. 3 hours seminar; 3 semester hours.

HASS552. CORRUPTION AND DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS552,
Addresses the problem of corruption and its impact on development. Readings are multidisciplinary and include policy studies, economics, and political science. Students will acquire an understanding of what constitutes corruption, how it negatively affects development, and what they, as engineers in a variety of professional circumstances, might do in circumstances in which bribe paying or taking might occur. 3 hours lecture and discussion; 3 semester hours.

HASS558. NATURAL RESOURCES AND DEVELOPMENT. 3.0 Semester Hrs.
Equivalent with LAIS558,
Examines the relationship between natural resources and development. It begins by discussing theories of development and how those theories account for specific choices among resource abundant countries. From the theoretical readings, students examine sector specific topics in particular cases. These subjects include oil and natural gas in African and Central Asian countries; hard rock mining in West Africa and East Asia; gemstone mining in Southern and West Africa; contracting in the extractive industries; and corporate social responsibility. Readings are multidisciplinary and draw from policy studies, economics, and political science to provide students an understanding of different theoretical approaches from the social sciences to explain the relationship between abundant natural resources and development. 3 hours lecture and discussion; 3 semester hours.

HASS560. GLOBAL GEOPOLITICS. 3.0 Semester Hrs.
Equivalent with LAIS560,
Examines geopolitical theories and how they help us explain and understand contemporary developments in the world. Empirical evidence from case studies help students develop a deeper understanding of the interconnections between the political, economic, social, cultural and geographic dimensions of governmental policies and corporate decisions. Prerequisites: any two IPE courses at the 300-level, or one IPE course at the 400 level. 3 hours lecture and discussion; 3 semester hours.

HASS565. SCIENCE, TECHNOLOGY, AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS565,
Provides an introduction to foundational concepts, themes, and questions developed within the interdisciplinary field of science and technology studies (STS). Readings address anthropological understandings of laboratory practice, sociological perspectives on the settling of techno-scientific controversies, historical insights on the development of scientific institutions, philosophical stances on the interactions between technology and humans, and relationships between science and democracy. Students complete several writing assignments, present material from readings and research, and help to facilitate discussion. 3 hours lecture and discussion; 3 semester hours.

HASS586. SCIENCE AND TECHNOLOGY POLICY. 3.0 Semester Hrs.
Equivalent with LAIS586,
Examines current issues relating to science and technology policy in the United States and, as appropriate, in other countries. 3 hours lecture and discussion; 3 semester hours.

HASS587. ENVIRONMENTAL POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS587,
Explores environmental policies and the political and governmental processes that produce them. Group discussion and independent research on specific environmental issues. Primary but not exclusive focus on the U.S. 3 hours lecture and discussion; 3 semester hours.

HASS588. WATER POLITICS AND POLICY. 3.0 Semester Hrs.
Equivalent with LAIS588,
Examines water policies and the political and governmental processes that produce them, as an example of natural resource politics and policy in general. Group discussion and independent research on specific politics and policy issues. Primary but not exclusive focus on the U.S. 3 hours lecture and discussion; 3 semester hours.

HASS590. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with LAIS590,
(II) The course begins with a brief introduction to global energy production and conservation, focusing on particular case studies that highlight the relationship among energy, society, and community in different contexts. The course examines energy successes and failures wherein communities, governments, and/or energy companies come together to promote socially just and economically viable forms of energy production/conservation. The course also explores conflicts driven by energy development. These case studies are supplemented by the expertise of guest speakers from industry, government, NGOs, and elsewhere. Areas of focus include questioning the forward momentum of energy production, its social and environmental impact, including how it distributes power, resources and risks across different social groups and communities. 3 hours seminar; 3 semester hours.

HASS591. ENERGY POLITICS. 3.0 Semester Hrs.
(I) We will use political science approaches, theories, and methods to investigate the global, regional, state, and local politics of renewable and non-renewable energy, spanning all uses: transportation, heating and cooling, and electricity. We will look at the politics behind energy in a subset of countries to be chosen by the class, such as China, Brazil, India, Austria, Spain, Venezuela, and Germany. We will then focus on energy in Colorado (and possibly a few other US states), conducting primary research on the stakeholders and the relevant political outcomes for non-renewables and renewables, making comparisons between the two groups. We will work with energy companies, non-governmental organizations, university and research entities, government representatives, and local activists. 3 lecture hours, 3 semester hours.

HASS592. ENERGY AND SECURITY POLICY. 3.0 Semester Hrs.
(II) Energy and Security Policy is a graduate course that applies a social science lens to understanding the intersections between national and international security concerns and energy. In this course, we will examine these intersections through a case study approach that includes directed readings, such as books and peer-reviewed journal articles, that incorporate student-led discussions and research projects. By exploring various energy security scenarios, such as restricted access to oil and gas, graduate students will gain a comprehensive understanding of the energy-security nexus and the role governments and policies play in enhancing or limiting security. 3 hours lecture, 3 semester hours.

HASS593. NATURAL RESOURCES & ENERGY POLICY: THEORIES AND PRACTICE. 3.0 Semester Hrs.
(I) This course introduces students to the policy-making process, drawing on a variety of theoretical approaches, geographic locations (within the US and in other countries), and resources and energy issues. Coordinated by the NREP Graduate Director, speakers will be from HASS, Economics and Business, Petroleum Engineering, Mining, and other departments with policy expertise, as well as from others who influence and create public and private policy. In the second half of the course, students will conduct original research projects that focus on natural resources and energy, applying theoretical frameworks they have learned from the speakers. 3 lecture hours, 3 semester hours.

HASS598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

HASS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

HASS601. ACADEMIC PUBLISHING. 2-3 Semester Hr.
Equivalent with LAIS601,
Students will finish this course with increased knowledge of general and discipline - specific writing conversations as well as the ability to use that knowledge in publishing portions of theses or dissertations. Beyond the research article, students will also have the opportunity to learn more about genres such as conference abstracts, conference presentations, literature reviews, and research funding proposals. Prerequisite: Must have completed one full year (or equivalent) of graduate school course work. Variable credit: 2 or 3 semester hours.

HASS698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

HASS699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

HASS707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with LAIS707,
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

MATERIALS SCIENCE (MLGN)

MLGN500. PROCESSING, MICROSTRUCTURE, AND PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
(II) A summary of the important relationships between the processing, microstructure, and properties of materials. Topics include electronic structure and bonding, crystal structures, lattice defects and mass transport, glasses, phase transformation, important materials processes, and properties including: mechanical and rheological, electrical conductivity, magnetic, dielectric, optical, thermal, and chemical. In a given year, one of these topics will be given special emphasis. Another area of emphasis is phase equilibria. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN501. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
(I) Application of X-ray diffraction techniques for crystal and molecular structure determination of minerals, inorganic and organometallic compounds. Topics include the heavy atom method, data collection by moving film techniques and by diffractometers, Fourier methods, interpretation of Patterson maps, refinement methods, and direct methods. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

MLGN502. SOLID STATE PHYSICS. 3.0 Semester Hrs.
An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. (Graduate students in physics may register only for PHGN440.) Prerequisite: PH320. 3 hours lecture; 3 semester hours.

MLGN503. CHEMICAL BONDING IN MATERIALS. 3.0 Semester Hrs.
(I) Introduction to chemical bonding theories and calculations and their applications to solids of interest to materials science. The relationship between a material's properties and the bonding of its atoms will be examined for a variety of materials. Includes an introduction to organic polymers. Computer programs will be used for calculating bonding parameters. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN504. SOLID STATE THERMODYNAMICS. 3.0 Semester Hrs.
(I) Thermodynamics applied to solid state reactions, binary and ternary phase diagrams, point, line and planar defects, interfaces, and electrochemical concepts. Prerequisites: none. 3 hours lecture; 3 semester hours.

MLGN505. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
(I) Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Prerequisite: MTGN348. 3 hours lecture; 3 hours lab; 3/4 semester hours. *This is a 3 credit-hour graduate course in the Materials Science Program and a 4 credit-hour undergraduate-course in the MTGN program.

MLGN506. TRANSPORT IN SOLIDS. 3.0 Semester Hrs.
(II) Thermal and electrical conductivity. Solid state diffusion in metals and metal systems. Kinetics of metallurgical reactions in the solid state. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MLGN509. SOLID STATE CHEMISTRY. 3.0 Semester Hrs.
(I) Dependence on properties of solids on chemical bonding and structure; principles of crystal growth, crystal imperfections, reactions and diffusion in solids, and the theory of conductors and semiconductors. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

MLGN510. SURFACE CHEMISTRY. 3.0 Semester Hrs.
Equivalent with CHGN410,
(I) Introduction to colloid systems, capillarity, surface tension and contact angle, adsorption from solution, micelles and microemulsions, the solid/gas interface, surface analytical techniques, Van Der Waal forces, electrical properties and colloid stability, some specific colloid systems (clays, foams and emulsions). Students enrolled for graduate credit in MLGN510 must complete a special project. Prerequisite: DCGN209 or DCGN210. 3 hours lecture; 3 semester hours.

MLGN511. KINETIC CONCERNS IN MATERIALS PROCESSING I. 3.0 Semester Hrs.
Equivalent with EGGN555,
(I) Introduction to the kinetics of materials processing, with emphasis on the momentum, heat and mass transport. Discussion of the basic mechanism of transport in gases, liquids and solids. Prerequisite: MTGN352, MTGN361, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MLGN512. CERAMIC ENGINEERING. 3.0 Semester Hrs.
(II) Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours. lecture; 3 semester hours.

MLGN513. PROBLEM SOLVING IN MATERIALS SCIENCE. 3.0 Semester Hrs.
(I) Review the theoretical aspects of various physical phenomena of major importance to materials scientists. Develop mathematical models from these theories, and construct quantitative solution procedures based on analytical and numerical techniques. Prerequisite: MATH225. 3 hours lecture; 3 semester hours.

MLGN515. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
(II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing, and microstructure on the electrical properties will be discussed, along with functions, performance requirements, and testing methods of materials for each type of circuit component. The general topics covered are conductors, resistors, insulators, capacitors, energy convertors, magnetic materials, and integrated circuits. Prerequisites: PHGN200; MTGN311 or MLGN501; MTGN412/MLGN512,. 3 hours lecture; 3 semester hours.

MLGN516. PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
(II) A survey of the properties of ceramic materials and how these properties are determined by the chemical structure (composition), crystal structure, and the microstructure of crystalline ceramics and glasses. Thermal, optical, and mechanical properties of single-phase and multi-phase ceramics, including composites, are covered. Prerequisites: PHGN200, MTGN311 or MLGN501, MTGN412. 3 semester hours: 3 hours lecture.

MLGN517. SOLID MECHANICS OF MATERIALS. 3.0 Semester Hrs.
(I) Review mechanics of materials. Introduction to elastic and non-linear continua. Cartesian tensors and stresses and strains. Analytical solution of elasticity problems. Develop basic concepts of fracture mechanics. Prerequisite: EGGN320 or equivalent, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MLGN518. PHASE EQUILIBRIA IN CERAMICS SYSTEMS. 3.0 Semester Hrs.
(II) Application of one of four component oxide diagrams to ceramic engineering problems. Emphasis on refractories and glasses and their interaction with metallic systems. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MLGN519. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.
(I) An introduction to the principles of glass science and engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisites: MTGN311 or MLGN501; MLGN512/MTGN412. 3 hours lecture; 3 semester hours.

MLGN521. KINETIC CONCERNS IN MATERIAL PROCESSING II. 3.0 Semester Hrs.
(I, II) Advanced course to address the kinetics of materials processing, with emphasis in those processes that promote phase and structural transformations. Processes that involve precipitation, sintering, oxidation, solgel, coating, etc., will be discussed in detail. Prerequisite: MLGN511. 3 hours lecture; 3 semester hours.

MLGN523. APPLIED SURFACE AND SOLUTION CHEMISTRY. 3.0 Semester Hrs.
(II) Solution and surface chemistry of importance in mineral and metallurgical operations. Pre requisite: none. 3 semester hours. (Spring of odd years only.).

MLGN526. GEL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the science and technology of particulate and polymeric gels, emphasizing inorganic systems. Interparticle forces. Aggregation, network formation, percolation, and the gel transition. Gel structure, rheology, and mechanical properties. Application to solid-liquid separation operations (filtration, centrifugation, sedimentation) and to ceramics processing. Prerequisite: Graduate level status. 3 hours lecture; 3 semester hours. Spring of odd years only.

MLGN530. INTRODUCTION TO POLYMER SCIENCE. 3.0 Semester Hrs.
Chemistry and thermodynamics of polymers and polymer solutions. Reaction engineering of polymerization. Characterization techniques based on solution properties. Materials science of polymers in varying physical states. Processing operations for polymeric materials and use in separations. Prerequisite: CHGN221, MATH225, CHEN357. 3 hour lecture, 3 semester hours.

MLGN531. POLYMER ENGINEERING AND TECHNOLOGY. 3.0 Semester Hrs.
(II) This class provides a background in polymer fluid mechanics, polymer rheological response and polymer shape forming. The class begins with a discussion of the definition and measurement of material properties. Interrelationships among the material response functions are elucidated and relevant correlations between experimental data and material response in real flow situations are given. Processing operations for polymeric materials will then be addressed. These include the flow of polymers through circular, slit, and complex dies. Fiber spinning, film blowing, extrusion and co-extrusion will be covered as will injection molding. Graduate students are required to write a term paper and take separate examinations which are at a more advanced level. Prerequisite: CRGN307, EGGN351 or equivalent. 3 hours lecture; 3 semester hours.

MLGN535. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with
CBEN435,CBEN535,CHEN435,CHEN535,PHGN435,PHGN535,
(II) Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisite: none. 3 hours lecture; 3 semester hours.

MLGN536. ADVANCED POLYMER SYNTHESIS. 3.0 Semester Hrs.
(II) An advanced course in the synthesis of macromolecules. Various methods of polymerization will be discussed with an emphasis on the specifics concerning the syntheses of different classes of organic and inorganic polymers. Prerequisite: CHGN430, ChEN415, MLGN530. 3 hours lecture, 3 semester hours.

MLGN544. PROCESSING OF CERAMICS. 3.0 Semester Hrs.
(II) A description of the principles of ceramic processing and the relationship between processing and microstructure. Raw materials and raw material preparation, forming and fabrication, thermal processing, and finishing of ceramic materials will be covered. Principles will be illustrated by case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Field trips to local ceramic manufacturing operations are included. Prerequisites: MTGN311, MTGN331, and MTGN412/MLGN512. 3 hours lecture; 3 semester hours.

MLGN550. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.
(I) An introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques will be developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts will be developed and applied for the evaluation of manufacturing processes. The theory and application of designed experiments will be developed and applied for full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments will be carried out by graphical and statistical techniques. Computer software will be utilized for statistical process control and for the design and analysis of experiments. Prerequisite: none. 3 hours lecture, 3 semester hours.

MLGN552. INORGANIC MATRIX COMPOSITES. 3.0 Semester Hrs.
(I) An introduction to the processing, structure, properties and applications of metal matrix and ceramic matrix composites. Importance of structure and properties of both the matrix and the reinforcement and the types of reinforcement utilized, e.g., particulate, short fiber, continuous fiber, and laminates. Special emphasis will be placed on the development of properties such as electrical and thermal will also be examined. Prerequisite/Co-requisite: MTGN311, MTGN352, MTGN445/MLGN505. 3 hours lecture; 3 semester hours (Summer of even years only.).

MLGN555. POLYMER AND COMPLEX FLUIDS COLLOQUIUM. 1.0 Semester Hr.
Equivalent with BELS555,CBEN555,CHEN555,CHGN555,
The Polymer and Complex Fluids Group at the Colorado School of Mines combines expertise in the areas of flow and field based transport, intelligent design and synthesis as well as nanomaterials and nanotechnology. A wide range of research tools employed by the group includes characterization using rheology, scattering, microscopy, microfluidics and separations, synthesis of novel macromolecules as well as theory and simulation involving molecular dynamics and Monte Carlo approaches. The course will provide a mechanism for collaboration between faculty and students in this research area by providing presentations on topics including the expertise of the group and unpublished, ongoing campus research. Prerequisites: none. 1 hour lecture; 1 semester hour. Repeatable for credit to a maximum of 3 hours.

MLGN561. TRANSPORT PHENOMENA IN MATERIALS PROCESSING. 3.0 Semester Hrs.
(II) Fluid flow, heat and mass transfer applied to processing of materials. Rheology of polymers, liquid metal/particles slurries, and particulate solids. Transient flow behavior of these materials in various geometries, including infiltration of liquids in porous media. Mixing and blending. Flow behavior of jets, drainage of films and particle fluidization. Surface-tension-, electromagnetic-, and bubble-driven flows. Heat -transfer behavior in porous bodies applied to sintering and solidification of composites. Simultaneous heat-and-mass-transfer applied to spray drying and drying porous bodies. Prerequisites: ChEN307 or ChEN308 or MTGN461. 3 hours lecture; 3 semester hours.

MLGN563. POLYMER ENGINEERING: STRUCTURE, PROPERTIES AND PROCESSING. 3.0 Semester Hrs.
(II) An introduction to the structure and properties of polymeric materials, their deformation and failure mechanisms, and the design and fabrication of polymeric end items. The molecular and crystallographic structures of polymers will be developed and related to the elastic, viscoelastic, yield and fracture properties of polymeric solids and reinforced polymer composites. Emphasis will be placed on forming techniques for end item fabrication including: extrusion, injection molding, reaction injection molding, thermoforming, and blow molding. The design of end items will be considered in relation to: materials selection, manufacturing engineering, properties, and applications. Prerequisite: MTGN311 or equivalent. 3 hours lecture; 3 semester hours.

MLGN565. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES. 3.0 Semester Hrs.
(II) Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisites: MTGN445 or MLGN505. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MLGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN569,EGGN569,MTGN569,
(II) Investigate fundamentals of fuel-call operation and electrochemistry from a chemical thermodynamics and materials science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: EGGN371 or ChEN357 or MTGN351 Thermodynamics I, MATH225 Differential Equations. 3 credit hours.

MLGN570. BIOCOMPATIBILITY OF MATERIALS. 3.0 Semester Hrs.
(II) Introduction to the diversity of biomaterials and applications through examination of the physiologic environment in conjunction with compositional and structural requirements of tissues and organs. Appropriate domains and applications of metals, ceramics and polymers, including implants, sensors, drug delivery, laboratory automation, and tissue engineering are presented. Prerequisites: ESGN 301 or equivalent. 3 hours lecture; 3 semester hours.

MLGN572. BIOMATERIALS. 3.0 Semester Hrs.
Equivalent with MTGN572,
(I) A broad overview on materials science and engineering principles for biomedical applications with three main topics: 1) The fundamental properties of biomaterials; 2) The fundamental concepts in biology; 3) The interactions between biological systems with exogenous materials. Examples including surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions and thrombosis; biofilm and biomaterials-related pathological reactions. Basic principles of bio-mimetic materials synthesis and assembly will also be introduced. 3 hours lecture; 3 semester hours.

MLGN583. PRINCIPLES AND APPLICATIONS OF SURFACE ANALYSIS TECHNIQUES. 3.0 Semester Hrs.
(II) Instrumental techniques for the characterization of surfaces of solid materials. Applications of such techniques to polymers, corrosion, metallurgy, adhesion science, micro-electronics. Methods of analysis discussed: X-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), ion scattering spectroscopy (ISS), secondary ion mass spectroscopy (SIMS), Rutherford backscattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive X-ray analysis; principles of these methods, quantification, instrumentation, sample preparation. Prerequisite: B.S. in metallurgy, chemistry, chemical engineering, physics. 3 hours lecture; 3 semester hours. This course taught in alternate even numbered years.

MLGN589. MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
A review of the thermodynamic principles of work, energy, entropy, free energy, equilibrium, and phase transformations in single and multi-component systems. Students will apply these principles to a broad range of materials systems of current importance including solid state materials, magnetic and piezoelectric materials, alloys, chemical and electrochemical systems, soft and biological materials and nanomaterials. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours lecture, 3 semester hours.

MLGN591. MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
(I) A review of the thermodynamic principles of work, energy, entropy, free energy, equilibrium, and phase transformations in single and multi-component systems. Students will apply these principles to a broad range of materials systems of current importance including solid state materials, magnetic and piezoelectric materials, alloys, chemical and electrochemical systems, soft and biological materials and nanomaterials. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours lecture, 3 semester hours.

MLGN592. ADVANCED MATERIALS KINETICS AND TRANSPORT. 3.0 Semester Hrs.
(I) A broad treatment of homogenous and heterogeneous kinetic transport and reaction processes in the gas, liquid, and solid states, with a specific emphasis on heterogeneous kinetic processes involving gas/solid, liquid/solid, and solid/solid systems. Reaction rate theory, nucleation and growth, and phase transformations will be discussed. A detailed overview of mass, heat, and charge transport in condensed phases is provided including a description of fundamental transport mechanisms, the development of general transport equations, and their application to a number of example systems. Prerequisites: A 300 level or higher course in thermodynamics, introductory college chemistry, electricity and magnetism, differential equations. 3 semester hours.

MLGN593. BONDING, STRUCTURE, AND CRYSTALLOGRAPHY. 3.0 Semester Hrs.
(I) This course will be an overview of condensed matter structure from the atomic scale to the mesoscale. Students will gain a perspective on electronic structure as it relates to bonding, long range order as it relates to crystallography and amorphous structures, and extend these ideas to nanostructure and microstructure. Examples relating to each hierarchy of structure will be stressed, especially as they relate to reactivity, mechanical properties, and electronic and optical properties. Prerequisites: A 300 level or higher course in thermodynamics. 3 semester hours.

MLGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MLGN599. CASE STUDY MATERIALS SCIENCE. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MLGN607. CONDENSED MATTER. 3.0 Semester Hrs.
(I) Principles and applications of the quantum theory of electronic in solids: structure and symmetry, electron states and excitations in metals; transport properties. Prerequisite: PHGN520 and PHGN440/MLGN502. 3 hours lecture; 3 semester hours.

MLGN625. MOLECULAR SIMULATION METHODS. 3.0 Semester Hrs.
(I Even Years), Principles and practice of modern computer simulation techniques used to understand solids, liquids, and gases. Review of the statistical foundation of thermodynamics followed by in-depth discussion of Monte Carlo and Molecular Dynamics techniques. Discussion of intermolecular potentials, extended ensembles, and mathematical algorithms used in molecular simulations. Prerequisites: graduate level thermodynamics (required), statistical mechanics (recommended). 3 semester hours.

MLGN634. ADVANCED TOPICS IN THERMODYNAMICS. 3.0 Semester Hrs.
Advanced study of thermodynamic theory and application of thermodynamic principles. Possible topics include stability, critical phenomena, chemical thermodynamics, thermodynamics of polymer solutions and thermodynamics of aqueous and ionic solutions. Prerequisite: none. 1 to 3 semester hours.

MLGN635. POLYMER REACTION ENGINEERING. 3.0 Semester Hrs.
This class is aimed at engineers with a firm technical background who wish to apply that background to polymerization production techniques. The class begins with a review of the fundamental concepts of reaction engineering, introduces the needed terminology and describes different reactor types. The applied kinetic models relevant to polymerization reaction engineering are then developed. Next, mixing effects are introduced; goodness of mixing and effects on reactor performance are discussed. Thermal effects are then introduced and the subjects of thermal runaway, thermal instabilities, and multiple steady states are included. Reactive processing, change in viscosity with the extent of reaction and continuous drag flow reactors are described. Polymer de-volatilization constitutes the final subject of the class. Prerequisites: CRGN518 or equivalent. 3 hours lecture; 3 semester hours.

MLGN648. CONDENSED MATTER II. 3.0 Semester Hrs.
(II) Principles and applications of the quantum theory of electronic and phonons in solids; phonon states in solids; transport properties; electron states and excitation in semiconductors and insulators; magnetism; superconductivity. Prerequisite: PHGN640/MLGN607. 3 hours lecture; 3 semester hours.

MLGN673. STRUCTURE AND PROPERTIES OF POLYMERS. 3.0 Semester Hrs.
This course will provide an understanding of structure- properties relations in polymeric materials. The topics include: phase separation, amorphous structures, crystalline structures, liquid crystals, glass-rubber transition behavior, rubber elasticity, viscoelasticity, mechanical properties of polymers, polymer forming processes, and electrical properties of polymers. Prerequisite: MLGN563. 3 hours lecture; 3 semester hours.

MLGN696. VAPOR DEPOSITION PROCESSES. 3.0 Semester Hrs.
(II) Introduction to the fundamental physics and chemistry underlying the control of vapor deposition processes for the deposition of thin films for a variety of applications, e.g.,corrosion/oxidation resistance, decorative coatings, electronic and magnetic thin films. Emphasis on the vapor deposition processes and the control of process variables rather than the structure and properties of the thin films. Prerequisites: MTGN351, MTGN461, or equivalent courses. 3 hours lecture; 3 semester hours.

MLGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MLGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MLGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

MATHEMATICS (MATH)

MATH100. INTRODUCTORY TOPICS FOR CALCULUS. 3.0 Semester Hrs.
(S) An introduction and/or review of topics which are essential to the background of an undergraduate student at CSM. This course serves as a preparatory course for the Calculus curriculum and includes material from Algebra, Trigonometry, Mathematical Analysis, and Calculus. Topics include basic algebra and equation solving, solutions of inequalities, trigonometric functions and identities, functions of a single variable, continuity, and limits of functions. Does not apply toward undergraduate degree or GPA. 3 hours lecture; 3 semester hours.

MATH111. CALCULUS FOR SCIENTISTS AND ENGINEERS I. 4.0 Semester Hrs.
Equivalent with MACS111,
(I, II, S) First course in the calculus sequence, including elements of plane geometry. Functions, limits, continuity, derivatives and their application. Definite and indefinite integrals; Prerequisite: precalculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH112. CALCULUS FOR SCIENTISTS AND ENGINEERS II. 4.0 Semester Hrs.
Equivalent with MACS112,MATH122,
(I, II, S) Vectors, applications and techniques of integration, infinite series, and an introduction to multivariate functions and surfaces. Prerequisite: Grade of C- or better in MATH111. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH113. CALCULUS FOR SCIENTISTS AND ENGINEERS II - SHORT FORM. 1.0 Semester Hr.
(I, II) This is a bridge course for entering freshmen and new transfer students to CSM who have either a score of 5 on the BC AP Calculus exam or who have taken an appropriate Calculus II course at another institution (determined by a departmental review of course materials). Two, three and n-dimensional space, vectors, curves and surfaces in 3-dimensional space, cylindrical and spherical coordinates, and applications of these topics. Prerequisites: none. 1 hour lecture; 1 semester hour.

MATH122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS. 4.0 Semester Hrs.
Equivalent with MATH112,
(I, II) Same topics as those covered in MATH112 but with additional material and problems. Prerequisites: Grade of C- or better in MATH111. 4 hours lecture; 4 semester hours.

MATH198. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH201. PROBABILITY AND STATISTICS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with MATH323,
(I,II,S) This course is an introduction to Probability and Statistics, including fundamentals of experimental design and data collection, the summary and display of data, elementary probability, propagation of error, discrete and continuous probability models, interval estimation, hypothesis testing, and linear regression with emphasis on applications to science and engineering. Prerequisites: MATH112, MATH122 or concurrent enrollment in MATH113. 3 hours lecture; 3 semester hours.

MATH213. CALCULUS FOR SCIENTISTS AND ENGINEERS III. 4.0 Semester Hrs.
(I, II, S) Multivariable calculus, including partial derivatives, multiple integrals, and vector calculus. Prerequisites: Grade of C- or better in MATH112 or MATH122 or Concurrent Enrollment in MATH113. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1.

MATH214. CALCULUS FOR SCIENTIST AND ENGINEERS III - SHORT FORM. 1.0 Semester Hr.
(I, II) This is a bridge course for entering freshmen and new transfer students to CSM who have taken an appropriate Calculus III course at another institution (determined by a departmental review of course materials). Vector Calculus including line and surface integrals with applications to work and flux, Green's Theorem, Stokes' Theorem and the Divergence Theorem. 1 hour lecture; 1 semester hour.

MATH223. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.
Equivalent with MACS223,
(II) Same topics as those covered in MATH213 but with additional material and problems. Prerequisite: Grade of C- or better in MATH122. 4 hours lecture; 4 semester hours.

MATH224. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.
(I) Early introduction of vectors, linear algebra, multivariable calculus. Vector fields, line and surface integrals. Prerequisite: Grade of C- or better in MATH122. 4 hours lecture; 4 semester hours.

MATH225. DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
Equivalent with MACS225,MACS315,
(I, II, S) Classical techniques for first and higher order equations and systems of equations. Laplace transforms. Phase-plane and stability analysis of non-linear equations and systems. Applications from physics, mechanics, electrical engineering, and environmental sciences. Prerequisites: Grade of C- or better in MATH112 or MATH122 or Concurrent Enrollment in MATH113. 3 hours lecture; 3 semester hours.

MATH235. DIFFERENTIAL EQUATIONS HONORS. 3.0 Semester Hrs.
Equivalent with MACS325,
(II) Same topics as those covered in MATH225 but with additional material and problems. Prerequisite: Grade of C- or better in MATH112 or MATH122 or Concurrent Enrollment in MATH113. 3 hours lecture; 3 semester hours.

MATH298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH300. FOUNDATIONS OF ADVANCED MATHEMATICS. 3.0 Semester Hrs.
(I) (WI) This course is an introduction to communication in mathematics. This writing intensive course provides a transition from the Calculus sequence to theoretical mathematics curriculum in CSM. Topics include logic and recursion, techniques of mathematical proofs, reading and writing proofs. Prerequisites: MATH112 or MATH122. 3 hours lecture; 3 semester hours.

MATH301. INTRODUCTION TO ANALYSIS. 3.0 Semester Hrs.
Equivalent with MATH401,
(II) This course is a first course in real analysis that lays out the context and motivation of analysis in terms of the transition from power series to those less predictable series. The course is taught from a historical perspective. It covers an introduction to the real numbers, sequences and series and their convergence, real-valued functions and their continuity and differentiability, sequences of functions and their pointwise and uniform convergence, and Riemann-Stieltjes integration theory. Prerequisite: MATH300. 3 hours lecture; 3 semester hours.

MATH307. INTRODUCTION TO SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
Equivalent with CSCI407,MATH407,
(I, II, S) This course is designed to introduce scientific computing to scientists and engineers. Students in this course will be taught various numerical methods and programming techniques to solve basic scientific problems. Emphasis will be made on implementation of various numerical and approximation methods to efficiently simulate several applied mathematical models. Prerequisites: MATH213 or MATH223 or MATH224. Co-requisites: MATH225 or MATH235. 3 hours lecture; 3 semester hours.

MATH310. INTRODUCTION TO MATHEMATICAL MODELING. 4.0 Semester Hrs.
(S) An introduction to modeling and communication in mathematics. A writing intensive course providing a transition from the core math sequence to the upper division AMS curriculum. Topics include a variety of mathematical and statistical modeling techniques. Students will formulate and solve applied problems and will present results orally and in writing. In addition, students will be introduced to the mathematics software that will be used in upper division courses. Prerequisites: MATH201 and MATH225. 3 hours lecture; 3 hours lab; 4 semester hours.

MATH331. MATHEMATICAL BIOLOGY. 3.0 Semester Hrs.
Equivalent with BELS331,BELS433,MACS433,MATH433,
(I, II) This course will discuss methods for building and solving both continuous and discrete mathematical models. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Modern Control Theory will be introduced and used to model living systems. Some concepts related to self-organizing systems will be introduced. Prerequisites: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH332. LINEAR ALGEBRA. 3.0 Semester Hrs.
Equivalent with MACS332,
(I, II) Systems of linear equations, matrices, determinants and eigenvalues. Linear operators. Abstract vector spaces. Applications selected from linear programming, physics, graph theory, and other fields. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH334. INTRODUCTION TO PROBABILITY. 3.0 Semester Hrs.
Equivalent with MACS334,MACS434,
(I) An introduction to the theory of probability essential for problems in science and engineering. Topics include axioms of probability, combinatorics, conditional probability and independence, discrete and continuous probability density functions, expectation, jointly distributed random variables, Central Limit Theorem, laws of large numbers. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH335. INTRODUCTION TO MATHEMATICAL STATISTICS. 3.0 Semester Hrs.
Equivalent with MACS435,
(II) An introduction to the theory of statistics essential for problems in science and engineering. Topics include sampling distributions, methods of point estimation, methods of interval estimation, significance testing for population means and variances and goodness of fit, linear regression, analysis of variance. Prerequisite: MATH334. 3 hours lecture, 3 semester hours.

MATH340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

MATH342. HONORS LINEAR ALGEBRA. 3.0 Semester Hrs.
Equivalent with MACS342,
(II) Same topics as those covered in MATH332 but with additional material and problems as well as a more rigorous presentation. Prerequisite: MATH213, MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH348. ADVANCED ENGINEERING MATHEMATICS. 3.0 Semester Hrs.
Equivalent with MACS348,
(I, II, S) Introduction to partial differential equations, with applications to physical phenomena. Fourier series. Linear algebra, with emphasis on sets of simultaneous equations. This course cannot be used as a MATH elective by MCS or AMS majors. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.
(I, II) This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines and regular languages. Prerequisite: MATH213 or MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH398. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH406. ALGORITHMS. 3.0 Semester Hrs.
Equivalent with CSCI406,MACS406,
(I, II) Divide-and-conquer: splitting problems into subproblems of a finite number. Greedy: considering each problem piece one at a time for optimality. Dynamic programming: considering a sequence of decisions in problem solution. Searches and traversals: determination of the vertex in the given data set that satisfies a given property. Techniques of backtracking, branch-andbound techniques, techniques in lower bound theory. Prerequisite: CSCI262 and (MATH213, MATH223 or MATH224, and MATH358/CSCI358). 3 hours lecture; 3 semester hours.

MATH408. COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
(I) This course is designed to introduce computational methods to scientists and engineers for developing differential equations based computer models. Students in this course will be taught various numerical methods and programming techniques to simulate systems of nonlinear ordinary differential equations. Emphasis will be on implementation of various numerical and approximation methods to efficiently simulate several systems of nonlinear differential equations. Prerequisite: MATH307. 3 hours lecture, 3 semester hours.

MATH424. INTRODUCTION TO APPLIED STATISTICS. 3.0 Semester Hrs.
(I) Linear regression, analysis of variance, and design of experiments, focusing on the construction of models and evaluation of their fit. Techniques covered will include stepwise and best subsets regression, variable transformations, and residual analysis. Emphasis will be placed on the analysis of data with statistical software. Prerequisites: MATH201 or MATH335 and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH432. SPATIAL STATISTICS. 3.0 Semester Hrs.
(I) Modeling and analysis of data observed in a 2- or 3-dimensional region. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes. Prerequisite: MATH335. Corequisite: MATH424. 3 hours lecture; 3 semester hours.

MATH436. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.
(II) Modern methods for constructing and evaluating statistical models. Topics include generalized linear models, generalized additive models, hierarchical Bayes methods, and resampling methods. Time series models, including moving average, autoregressive, and ARIMA models, estimation and forecasting, confidence intervals. Prerequisites: MATH335 and MATH424. 3 hours lecture; 3 semester hours.

MATH437. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.
(II) Introduction to applied multivariate techniques for data analysis. Topics include principal components, cluster analysis, MANOVA and other methods based on the multivariate Gaussian distribution, discriminant analysis, classification with nearest neighbors. Prerequisites: MATH335 or MATH201 and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH438. STOCHASTIC MODELS. 3.0 Semester Hrs.
(II) An introduction to stochastic models applicable to problems in engineering, physical science, economics, and operations research. Markov chains in discrete and continuous time, Poisson processes, and topics in queuing, reliability, and renewal theory. Prerequisite: MATH334. 3 hours lecture, 3 semester hours.

MATH439. SURVIVAL ANALYSIS. 3.0 Semester Hrs.
(I) Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, hypothesis testing, the proportional hazards model, model diagnostics. Prerequisite: MATH335. 3 hours lecture; 3 semester hours.

MATH440. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
Equivalent with CSCI440,
(I) This course is designed to facilitate students' learning of parallel programming techniques to efficiently simulate various complex processes modeled by mathematical equations using multiple and multi-core processors. Emphasis will be placed on implementation of various scientific computing algorithms in FORTRAN 90 and its variants using MPI and OpenMP. Prerequisites: MATH307 or CSCI407. 3 hours lecture; 3 semester hours.

MATH441. COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with CSCI441,
(I) Data structures suitable for the representation of structures, maps, three-dimensional plots. Algorithms required for windowing, color plots, hidden surface and line, perspective drawings. Survey of graphics software and hardware systems. Prerequisite: CSCI262. 3 hours lecture, 3 semester hours.

MATH444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with CSCI444,
(I, II) This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techiques that can be used to develop high-quality computer graphics software. In particular, the crouse will cover global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Prerequistes: Basic understanding of computer graphics and prior exposure to graphics-related programming, for example, MATH441. 3 lecture hours, 3 credit hours.

MATH447. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with CSCI447,
(I) Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on modern visualization techniques applicable to spatial data such as scalar, vector and tensor fields. In particular, the course will cover volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Basic understanding of computer graphics and analysis of algorithms required. Prerequisites: CSCI262 and MATH441. 3 lecture hours, 3 semester hours.

MATH454. COMPLEX ANALYSIS. 3.0 Semester Hrs.
Equivalent with MACS454,
(II) The complex plane. Analytic functions, harmonic functions. Mapping by elementary functions. Complex integration, power series, calculus of residues. Conformal mapping. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture, 3 semester hours.

MATH455. PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
(I, II) Linear partial differential equations, with emphasis on the classical second-order equations: wave equation, heat equation, Laplace's equation. Separation of variables, Fourier methods, Sturm-Liouville problems. Prerequisites: MATH225 or MATH235 and MATH213 or MATH223 or MATH224. 3 hours lecture; 3 semester hours.

MATH457. INTEGRAL EQUATIONS. 3.0 Semester Hrs.
(I) This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Prerequisites: MATH332 or MATH342, and MATH455. 3 hours lecture; 3 semester hours.

MATH458. ABSTRACT ALGEBRA. 3.0 Semester Hrs.
(I) This course is an introduction to the concepts of contemporary abstract algebra and applications of those concepts in areas such as physics and chemistry. Topics include groups, subgroups, isomorphisms and homomorphisms, rings, integral domains and fields. Prerequisites: MATH300. 3 hours lecture; 3 semester hours.

MATH459. ASYMPTOTICS. 3.0 Semester Hrs.
Equivalent with MATH559,
(I) Asymptotic methods are used to find approximate solutions to problems when exact solutions are unavailable or too complicated to be useful. A broad range of asymptotic methods is developed, covering algebraic problems, integrals and differential equations. Prerequisites: MATH213 and MATH225. 3 hours lecture; 3 semester hours.

MATH472. MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE. 3.0 Semester Hrs.
(II) This course will focus on mathematical and computational techniques applied to neuroscience. Topics will include nonlinear dynamics, hysteresis, the cable equation, and representative models such as Wilson-Cowan, Hodgkin-Huxley, and FitzHugh-Nagumo. Applications will be motivated by student interests. In addition to building basic skills in applied math, students will gain insight into how mathematical sciences can be used to model and solve problems in neuroscience; develop a variety of strategies (computational, theoretical, etc.) with which to approach novel mathematical situations; and hone skills for communicating mathematical ideas precisely and concisely in an interdisciplinary context. In addition, the strong computational component of this course will help students to develop computer programming skills and apply appropriate technological tools to solve mathematical problems. Prerequisite: MATH331. 3 hours lecture; 3 semester hours.

MATH474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with CSCI474,
(II) This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisites: CSCI262, MATH334/MATH335, MATH358. 3 credit hours.

MATH482. STATISTICS PRACTICUM (CAPSTONE). 3.0 Semester Hrs.
(II) This is the capstone course in the Statistics option. Students will apply statistical principles to data analysis through advanced work, leading to a written report and an oral presentation. Choice of project is arranged between the student and the individual faculty member who will serve as advisor. Prerequisites: MATH335 and MATH424. 3 hours lecture; 3 semester hours.

MATH484. MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE). 3.0 Semester Hrs.
(II) This is the capstone course in the Computational and Applied Mathematics option. Students will apply computational and applied mathematics modeling techniques to solve complex problems in biological, engineering and physical systems. Mathematical methods and algorithms will be studied within both theoretical and computational contexts. The emphasis is on how to formulate, analyze and use nonlinear modeling to solve typical modern problems. Prerequisites: MATH331, MATH307, and MATH455. 3 hours lecture; 3 semester hours.

MATH491. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
Equivalent with MACS491,
(I) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH492. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.
(II) (WI) Individual investigation under the direction of a department faculty member. Written report required for credit. Prerequisite: none. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH500. LINEAR VECTOR SPACES. 3.0 Semester Hrs.
(I) Finite dimensional vector spaces and subspaces: dimension, dual bases, annihilators. Linear transformations, matrices, projections, change of basis, similarity. Determinants, eigenvalues, multiplicity. Jordan form. Inner products and inner product spaces with orthogonality and completeness. Prerequisite: MATH301, MATH332. 3 hours lecture; 3 semester hours.

MATH501. APPLIED ANALYSIS. 3.0 Semester Hrs.
(I) Fundamental theory and tools of applied analysis. Students in this course will be introduced to Banach, Hilbert, and Sobolev spaces; bounded and unbounded operators defined on such infinite dimensional spaces; and associated properties. These concepts will be applied to understand the properties of differential and integral operators occurring in mathematical models that govern various biological, physical and engineering processes. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH502. REAL AND ABSTRACT ANALYSIS. 3.0 Semester Hrs.
(I) Normed space R, open and closed sets. Lebesgue measure, measurable sets and functions. Lebesgue integral and convergence theorems. Repeated integration and integration by substitution. Lp spaces, Banach and Hilbert spaces. Weak derivatives and Sobalev spaces. Weak solutions of two-point boundary value problems. Prerequisites: MATH301 or equivalent. 3 hours lecture; 3 semester hours.

MATH503. FUNCTIONAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with MACS503,
(II) Properties of metric spaces, normed spaces and Banach spaces, inner product and Hilbert spaces. Fundamental theorems for normed and Banach spaces with applications. Orthogonality and orthonormal systems on Hilbert spaces with applications to approximation theory. Compact, bounded and unbounded operators. Duality, adjoint, self-adjoint, Hilbert-adjoint operators. Spectral analysis of linear operators. Applications to differential and integral equations. Prerequisites: MATH502. 3 hours lecture; 3 semester hours.

MATH506. COMPLEX ANALYSIS II. 3.0 Semester Hrs.
(II) Analytic functions. Conformal mapping and applications. Analytic continuation. Schlicht functions. Approximation theorems in the complex domain. Taught every other year. Prerequisite: MATH454. 3 hours lecture; 3 semester hours.

MATH510. ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with MACS510,
(I) Topics to be covered: basic existence and uniqueness theory, systems of equations, stability, differential inequalities, Poincare-Bendixon theory, linearization. Other topics from: Hamiltonian systems, periodic and almost periodic systems, integral manifolds, Lyapunov functions, bifurcations, homoclinic points and chaos theory. Offered even years. Prerequisite: (MATH225 or MATH235) and (MATH332 or MATH342). 3 hours lecture; 3 semester hours.

MATH514. APPLIED MATHEMATICS I. 3.0 Semester Hrs.
(I) The major theme in this course is various non-numerical techniques for dealing with partial differential equations which arise in science and engineering problems. Topics include transform techniques, Green's functions and partial differential equations. Stress is on applications to boundary value problems and wave theory. Prerequisite: MATH455 or equivalent. 3 hours lecture; 3 semester hours.

MATH515. APPLIED MATHEMATICS II. 3.0 Semester Hrs.
(II) Topics include integral equations, applied complex variables, an introduction to asymptotics, linear spaces and the calculus of variations. Stress is on applications to boundary value problems and wave theory, with additional applications to engineering and physical problems. Prerequisite: MATH514. 3 hours lecture; 3 semester hours.

MATH530. STATISTICAL METHODS I. 3.0 Semester Hrs.
(I) Introduction to probability, random variables, and discrete and continuous probability models. Elementary simulation. Data summarization and analysis. Confidence intervals and hypothesis testing for means and variances. Chi square tests. Distribution-free techniques and regression analysis. Prerequisite: MATH213 or equivalent. 3 hours lecture; 3 semester hours.

MATH531. STATISTICAL METHODS II. 3.0 Semester Hrs.
Equivalent with MACS531,
(II) Continuation of MATH530. Multiple regression and trend surface analysis. Analysis of variance. Experimental design (Latin squares, factorial designs, confounding, fractional replication, etc.) Nonparametric analysis of variance. Topics selected from multivariate analysis, sequential analysis or time series analysis. Prerequisite: MATH201 or MATH530 or MATH535. 3 hours lecture; 3 semester hours.

MATH532. SPATIAL STATISTICS. 3.0 Semester Hrs.
(I) Modeling and analysis of data observed on a 2 or 3-dimensional surface. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes, spatio-temporal modeling. Course is offered every other year on even years. Prerequisites: MATH424 or MATH531. 3 hours lecture; 3 semester hours.

MATH534. MATHEMATICAL STATISTICS I. 3.0 Semester Hrs.
(I) The basics of probability, discrete and continuous probability distributions, sampling distributions, order statistics, convergence in probability and in distribution, and basic limit theorems, including the central limit theorem, are covered. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH535. MATHEMATICAL STATISTICS II. 3.0 Semester Hrs.
Equivalent with MACS535,
(II) The basics of hypothesis testing using likelihood ratios, point and interval estimation, consistency, efficiency, sufficient statistics, and some nonparametric methods are presented. Prerequisite: MATH534 or equivalent. 3 hours lecture; 3 semester hours.

MATH536. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.
(II) Modern extensions of the standard linear model for analyzing data. Topics include generalized linear models, generalized additive models, mixed effects models, and resampling methods. Offered every two years on odd years. Prerequisite: MATH335, MATH424. 3 hours lecture; 3 semester hours.

MATH537. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.
(II) Introduction to applied multivariate representations of data for use in data analysis. Topics include introduction to multivariate distributions; methods for data reduction, such as principal components; hierarchical and model-based clustering methods; factor analysis; canonical correlation analysis; multidimensional scaling; and multivariate hypothesis testing. Prerequisites: MATH 530 and MATH 332 or MATH 500. 3 hours lecture; 3.0 semester hours.

MATH538. STOCHASTIC MODELS. 3.0 Semester Hrs.
(II) An introduction to the mathematical principles of stochastic processes. Discrete- and continuous-time Markov processes, Poisson processes, Brownian motion. Offered every two years on even years. 3 hours lecture; 3 semester hours.

MATH539. SURVIVAL ANALYSIS. 3.0 Semester Hrs.
(I) Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, the proportional hazards model, model diagnostics. Offered on odd years. Prerequisite: MATH335, MATH535. 3 hours lecture; 3 semester hours.

MATH540. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.
(II) This course is designed to facilitate students? learning of parallel programming techniques to efficiently simulate various complex processes modeled by mathematical equations using multiple and multi-core processors. Emphasis will be placed on the implementation of various scientific computing algorithms in FORTRAN/C/C++ using MPI and OpenMP. Prerequisite: MATH307. 3 hours lecture; 3 semester hours.

MATH542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542,
(I) Advanced study of simulation techniques, random number, and variate generation. Monte Carlo techniques, simulation languages, simulation experimental design, variance reduction, and other methods of increasing efficiency, practice on actual problems. Prerequisite: CSCI262 (or equivalent), MATH323 (or MATH530 or equivalent). 3 hours lecture; 3 semester hours.

MATH544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with CSCI544,
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

MATH547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with CSCI547,
Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

MATH550. NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
Equivalent with MACS550,
(II) Numerical methods for solving partial differential equations. Explicit and implicit finite difference methods; stability, convergence, and consistency. Alternating direction implicit (ADI) methods. Weighted residual and finite element methods. Prerequisite: MATH225 or MATH235, and MATH332 or MATH342. 3 hours lecture; 3 semester hours.

MATH551. COMPUTATIONAL LINEAR ALGEBRA. 3.0 Semester Hrs.
Equivalent with MACS551,
(II) Numerical analysis of algorithms for solving linear systems of equations, least squares methods, the symmetric eigenproblem, singular value decomposition, conjugate gradient iteration. Modification of algorithms to fit the architecture. Error analysis, existing software packages. Prerequisites: MATH332, CSCI407/MATH407. 3 hours lecture; 3 semester hours.

MATH556. MODELING WITH SYMBOLIC SOFTWARE. 3.0 Semester Hrs.
(I) Case studies of various models from mathematics, the sciences and engineering through the use of the symbolic software package MATHEMATICA. Based on hands-on projects dealing with contemporary topics such as number theory, discrete mathematics, complex analysis, special functions, classical and quantum mechanics, relativity, dynamical systems, chaos and fractals, solitons, wavelets, chemical reactions, population dynamics, pollution models, electrical circuits, signal processing, optimization, control theory, and industrial mathematics. The course is designed for graduate students and scientists interested in modeling and using symbolic software as a programming language and a research tool. It is taught in a computer laboratory. Prerequisites: none. 3 hours lecture; 3 semester hours.

MATH557. INTEGRAL EQUATIONS. 3.0 Semester Hrs.
(I) This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Offered even years. Prerequisite: MATH332 or MATH342 and MATH455. 3 hours lecture; 3 semester hours.

MATH559. ASYMPTOTICS. 3.0 Semester Hrs.
Equivalent with MATH459,
(I) Exact methods for solving mathematical problems are not always available: approximate methods must be developed. Often, problems involve small parameters, and this can be exploited so as to derive approximations: these are known as asymptotic approximations. Many techniques for constructing asymptotic approximations have been devised. The course develops such approximations for algebraic problems, the evaluation of integrals, and the solutions of differential equations. Emphasis is placed on effective methods and, where possible, rigorous analysis. Prerequisites: Calculus and ordinary differential equations. 3 hours lecture; 3 semester hours.

MATH572. MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE. 3.0 Semester Hrs.
(II) This course will focus on mathematical and computational techniques applied to neuroscience. Topics will include nonlinear dynamics, hysteresis, the cable equation, and representative models such as Wilson-Cowan, Hodgkin-Huxley, and FitzHugh-Nagumo. Applications will be motivated by student interests. In addition to building basic skills in applied math, students will gain insight into how mathematical sciences can be used to model and solve problems in neuroscience; develop a variety of strategies (computational, theoretical, etc.) with which to approach novel mathematical situations; and hone skills for communicating mathematical ideas precisely and concisely in an interdisciplinary context. In addition, the strong computational component of this course will help students to develop computer programming skills and apply appropriate technological tools to solve mathematical problems. Prerequisite: MATH331. 3 hours lecture; 3 semester hours.

MATH574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with CSCI574,
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

MATH582. STATISTICS PRACTICUM. 3.0 Semester Hrs.
(II) This is the capstone course in the Statistics Option. The main objective is to apply statistical knowledge and skills to a data analysis problem, which will vary by semester. Students will gain experience in problem-solving; working in a team; presentation skills (both orally and written); and thinking independently. Prerequisites: MATH 201 or 530 and MATH 424 or 531. 3 hours lecture and discussion; 3 semester hours.

MATH589. APPLIED MATHEMATICS AND STATISTICS TEACHING SEMINAR. 1.0 Semester Hr.
(I) An introduction to teaching issues and techniques within the AMS department. Weekly, discussion-based seminars will cover practical issues such as lesson planning, grading, and test writing. Issues specific to the AMS core courses will be included. 1 hour lecture; 1.0 semester hour.

MATH598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH610. ADVANCED TOPICS IN DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.
(II) Topics from current research in ordinary and/or partial differential equations; for example, dynamical systems, advanced asymptotic analysis, nonlinear wave propagation, solitons. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH614. ADVANCED TOPICS IN APPLIED MATHEMATICS. 3.0 Semester Hrs.
(I) Topics from current literature in applied mathematics; for example, wavelets and their applications, calculus of variations, advanced applied functional analysis, control theory. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH616. INTRODUCTION TO MULTI-DIMENSIONAL SEISMIC INVERSION. 3.0 Semester Hrs.
(II) Introduction to high frequency inversion techniques. Emphasis on the application of this theory to produce a reflector map of the earth?s interior and estimates of changes in earth parameters across those reflectors from data gathered in response to sources at the surface or in the interior of the earth. Extensions to elastic media are discussed, as well. Includes high frequency modeling of the propagation of acoustic and elastic waves. Prerequisites: partial differential equations, wave equation in the time or frequency domain, complex function theory, contour integration. Some knowledge of wave propagation: reflection, refraction, diffraction. 3 hours lecture; 3 semester hours.

MATH650. ADVANCED TOPICS IN NUMERICAL ANALYSIS. 3.0 Semester Hrs.
(II) Topics from the current literature in numerical analysis and/or computational mathematics; for example, advanced finite element method, sparse matrix algorithms, applications of approximation theory, software for initial value ODE?s, numerical methods for integral equations. Prerequisite: none. 3 hours lecture; 3 semester hours.

MATH691. GRADUATE SEMINAR. 1.0 Semester Hr.
(I) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH692. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with CSCI692,MACS692,
(II) Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

MATH693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
(I, II) Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on under lying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

MATH698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MATH699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MATH707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

MECHANICAL ENGINEERING (MEGN)

MEGN200. INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE. 3.0 Semester Hrs.
(I, II, S) This course introduces programming skills using Matlab as a means to collect and analyze data and utilizes Arduinos as a platform for prototyping simple circuits and designs. Additionally, the course introduces basic probability and statistics through data sets and real time data collection. For design topics this course reinforces problem definition and identifying constraints and criteria, encourages multiple solutions, and introduces analysis in design through prototyping. Prerequisite: EDNS151 or EDNS155 or HNRS105 or HNRS115. 3 hours lecture; 3 semester hours.

MEGN201. MECHANICAL FIELD SESSION. 3.0 Semester Hrs.
Equivalent with EGGN235,
(I, II, S) This course reinforces basic drawing skills from Cornerstone Design, introduces SolidWorks tools to advance modeling skills, introduces machine shop skills (including safety and use of mill, lathe and CNC) and introduces GDnT practices important in fabrication and manufacturing, and prob-stats relevant to manufacturing. Prerequisite: EDNS151 or EDNS155. 3 hours lecture; 3 semester hours.

MEGN250. MULTIDISCIPLINARY ENGINEERING LABORATORY. 1.5 Semester Hr.
Equivalent with EGGN250,
(I, II) (WI) Laboratory experiments integrating instrumentation, circuits and power with computer data acquisitions and sensors. Sensor data is used to transition between science and engineering science. Engineering Science issues like stress, strains, thermal conductivity, pressure and flow are investigated using fundamentals of equilibrium, continuity, and conservation. Prerequisite: PHGN200. 0.6 hours lecture; 2.7 hours lab; 1.5 semester hours.

MEGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN300. INSTRUMENTATION & AUTOMATION. 3.0 Semester Hrs.
(I, II) This course will explore instrumentation and automation of electro-mechanical systems. Students will utilize LabView and electro-mechanical instrumentation to solve advanced engineering problems. Class activities and projects will highlight the utility of LabView for real-time instrumentation and control. Prerequisites: MEGN200, MEGN201. 2 hours lecture; 1 hour other; 3 semester hours.

MEGN301. MECHANICAL INTEGRATION & DESIGN. 2.0 Semester Hrs.
(I, II) Students will utilize the engineering design process and knowledge in systems level design to produce a mechanical product/process. Students will reverse engineer a product/process to emphasize the steps in the design process. Students will select a longer course project, which is intended to reinforce engineering skills from other courses. The project topics would parallel one of the four research disciplines in ME, and students would be able to choose a topic pathway that emphasizes opportunities for mechanical engineering graduates. Prerequisites: MEGN200, MEGN201, and MEGN300. 1 hour lecture, 1 hour other; 2 semester hours.

MEGN312. INTRODUCTION TO SOLID MECHANICS. 3.0 Semester Hrs.
(I, II, S) Introduction to the theory and application of the principles of Solid Mechanics by placing an early focus on free body diagrams, stress and strain transformations, and failure theories. Covered topics include: stress and stress transformation, strain and strain transformation, mechanical properties of materials, axial load, torsion, bending, transverse shear, combined loading, pressure vessels, failure theories, stress concentrations, thermal stress, deflection of beams and shafts, and column buckling. Upon completion of the course, students will be able to apply the principles of Solid Mechanics to the analysis of elastic structures under simple and combined loading, use free body diagrams in the analysis of structures, use failure theories to assess safety of design, and effectively communicate the outcomes of analysis and design problems. May not also receive credit for CEEN311. Prerequisites: CEEN241 (C- or better). Co-requisites: MEGN200. 3 hours lecture; 3 semester hours.

MEGN315. DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN315,
(I,II,S) Absolute and relative motions. Kinetics, work-energy, impulse-momentum, vibrations. Prerequisites: CEEN241 (C- or better) and MATH225 (C- or better). 3 hours lecture; 3 semester hours.

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0 Semester Hrs.
Equivalent with BELS325,BELS420,EGGN325,EGGN420,
(I) The application of mechanical engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering (more specifically, Biomechanical Engineering) has evolved over the past 50 years to address these challenges. Biomechanical Engineering includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomechanical Engineering and to prepare the student for more advanced Biomechanical coursework. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various mechanical engineering principles to the human body. Prerequisites: MEGN312 or CEEN311 and PHGN200. Co-requisites: MEGN315. 3 hours lecture; 3 semester hours.

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
Equivalent with EGGN340,EGGN340M,
(I,II,S) Supervised, full-time engineering related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Department Head prior to enrolling to clarify the educational objectives for their individual Co-op program. Prerequisites: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 3 semester hours credit will be granted once toward degree requirements. Credit earned in MEGN340, Cooperative Education, may be used as free elective credit hours if, in the judgment of the Department Head, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives requires the student to submit a Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements form obtained from the Career Center to the Department Head.

MEGN350. MULTIDISCIPLINARY ENGINEERING LABORATORY II. 1.5 Semester Hr.
Equivalent with EGGN350,
(I, II) (WI) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Fluid mechanics issues like compressible and incompressible fluid flow (mass and volumetric), pressure losses, pump characteristics, pipe networks, turbulent and laminar flow, cavitation, drag, and others are covered. Experimental stress analysis issues like compression and tensile testing, strain gage installation, Young's Modulus, stress vs. strain diagrams, and others are covered. Experimental stress analysis and fluid mechanics are integrated in experiments which merge fluid power of the testing machine with applied stress and displacement of material specimen. Co-requisites: MEGN351 or CEEN310 and CEEN311 or MEGN312. 0.6 hours lecture; 2.7 hours lab; 1.5 semester hours.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN351,
(I, II) Fluid properties, fluid statics, control-volume analysis, Bernoulli equation, differential analysis and Navier-Stokes equations, dimensional analysis, internal flow, external flow, open-channel flow, and turbomachinery. May not also receive credit for CEEN310 or PEGN251. Prerequisite: CEEN241 (C- or better) or MNGN317 (C- or better). 3 hours lecture; 3 semester hours.

MEGN361. THERMODYNAMICS I. 3.0 Semester Hrs.
Equivalent with EGGN371,
(I, II, S) A comprehensive treatment of thermodynamics from a mechanical engineering point of view. Thermodynamic properties of substances inclusive of phase diagrams, equations of state, internal energy, enthalpy, entropy, and ideal gases. Principles of conservation of mass and energy for steady-state and transient analyses. First and Second Law of thermodynamics, heat engines, and thermodynamic efficiencies. Application of fundamental principles with an emphasis on refrigeration and power cycles. May not also receive credit for CBEN210. Prerequisite: MATH213 (C- or better). 3 hours lecture; 3 semester hours.

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.
Equivalent with EGGN390,MEGN380,
(I, II, S) Introduction to a wide variety of manufacturing processes with emphasis on process selection and laboratory measurements of process conditions with product variables. Consideration of relations among material properties, process settings, tooling features and product attributes. Design and implementation of a process for manufacture of a given component. Manual and Automated manufacturing and their implementation in plant layouts. Understanding how to eliminate waste in manufacturing processes and enhance scheduling and satisfying client needs. Quality, tolerances and standards will be discussed along with their importance in a manufacturing setting. Prerequisites: MEGN312 and MTGN202. 3 lecture hours, 3 semester hours.

MEGN391. AUTOMOTIVE DESIGN: SAE COLLEGIATE DESIGN SERIES (FORMULA SAE). 1.0 Semester Hr.
(I, II) This course introduces students to automotive design and fabrication. Students will design, fabricate, test, and analyze a formula style race car for the Formula SAE Collegiate Design Series international competition. Provide engineering students an opportunity to develop engineering skills beyond the classroom in a team oriented, competitive, and hands-on environment. Students will learn about a broad range of automobile design topics to include vehicle dynamics, propulsion, chassis design, electrical systems and aerodynamic devices. Both theoretical and ?hands on? skills will be exercised. Additionally, students will learn basic mechanical drawing, analysis and fabrication skills. Special emphasis will be placed on workplace safety, teamwork and peer leadership. Finally, students will gain experience in program management to include budgeting, resource management, scheduling and solving real world ?open-ended? problems. Prerequisites: MEGN200. 1 hour lecture, 1 semester hour. Repeatable up to 3 hours.

MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN408. INTRODUCTION TO SPACE EXPLORATION. 1.0 Semester Hr.
Equivalent with EGGN408,
(I) Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminarstyle class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector. 1 lecture hour; 1 semester hour.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.
Equivalent with EGGN422,
(I, II) General theories of stress and strain; stress and strain transformations, principal stresses and strains, octahedral shear stresses, Hooke's law for isotropic material, and failure criteria. Introduction to elasticity and to energy methods. Torsion of non-circular and thin-walled members. Unsymmetrical bending and shear-center, curved beams, and beams on elastic foundations. Introduction to plate theory. Thick-walled cylinders and contact stresses. Prerequisite: CEEN311 (C- or better) or MEGN312 (C- or better). 3 hours lecture; 3 semester hours.

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.
Equivalent with EGGN478,
(II) Theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Analysis of free and forced vibrations to different types of loading - harmonic, impulse, periodic and general transient loading. Derive model systems using D'Alambert's principle, Lagrange's equations and Hamilton's principle. Analysis of natural frequencies and mode shapes. Role of damping in machines and structures. Analysis and effects of resonance. Use of the modal superposition method and the transient Duhamel integral method. Prerequisite: MEGN315 (C- or better). 3 hours lecture; 3 semester hours.

MEGN424. COMPUTER AIDED ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN413,
(I, II, S) This course introduces the student to the concept of computer-aided engineering. The major objective is to provide the student with the necessary background to use the computer as a tool for engineering analysis and design. The Finite Element Analysis (FEA) method and associated computational engineering software have become significant tools in engineering analysis and design. This course is directed to learning the concepts of FEA and its application to civil and mechanical engineering analysis and design. Note that critical evaluation of the results of a FEA using classical methods (from statics and mechanics of materials) and engineering judgment is employed throughout the course. Prerequisite: MEGN312 (C- or better) or CEEN311 (C- or better). 3 hours lecture; 3 semester hours.

MEGN425. ADVANCED COMPUTER AIDED ENGINEERING. 3.0 Semester Hrs.
(I,S) This course studies advanced topics in engineering analysis using the finite element method. The analyses are conducted using commercial FEA software. The advanced topics include: nonlinear large deformations and elasto-plastic behavior, steady and transient heat transfer and thermally induced stresses, mechanical vibrations and transient dynamic phenomena, deformations and stresses in mechanical and structural assemblies, and stress intensity phenomena. Note, the accuracy and validity of FEA results is assessed by comparison with results obtained with exact or approximate analytical methods wherever possible. Prerequisites: MEGN424. 3 hours lecture; 3 semester hours.

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.
Equivalent with BELS425,EGGN425,
(II) This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. Prerequisite: MEGN315, CEEN311 or MEGN312, MEGN330. 3 hours lecture; 3 semester hours.

MEGN435. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Equivalent with BELS426,EGGN426,
(II) Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties and interactions with the environment to construct detailed computer models and simulations. The course will culminate in individual class projects related to each student?s individual interests. Prerequisites: MEGN315 and MEGN330. 3 hours lecture; 3 semester hours.

MEGN436. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.
Equivalent with BELS428,BELS428,EGGN428,
Computational Biomechanics provides an introduction to the application of computer simulation to solve some fundamental problems in biomechanics and bioengineering. Musculoskeletal mechanics, medical image reconstruction, hard and soft tissue modeling, joint mechanics, and inter-subject variability will be considered. An emphasis will be placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of computational techniques. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is demonstrated. Prerequisites: MEGN424, MEGN330. 3 hours lecture, 3 semester hours. Fall odd years.

MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.
Equivalent with EGGN400,
(I, II) Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. EENG307 is recommended to be completed before this course. Prerequisites: CSCI261 and EENG281 or EENG282 or PHGN215. 2 hours lecture; 3 hours lab; 3 semester hours.

MEGN450. MULTIDISCIPLINARY ENGINEERING LABORATORY III. 1.0 Semester Hr.
Equivalent with EGGN450,
(I, II) Laboratory experiments integrating electrical circuits, fluid mechanics, stress analysis, and other engineering fundamentals using computer data acquisition and transducers. Students will design experiments to gather data for solving engineering problems. Examples are recommending design improvements to a refrigerator, diagnosing and predicting failures in refrigerators, computer control of a hydraulic fluid power circuit in a fatigue test, analysis of structural failures in an off-road vehicle and redesign, diagnosis and prediction of failures in a motor/generator system. Prerequisites: MEGN350 or EENG382. Co-requisites: EENG307. 3 hours lab; 1 semester hour.

MEGN451. FLUID MECHANICS II. 3.0 Semester Hrs.
Equivalent with EGGN473,
(II) Review of elementary fluid mechanics and engineering, two-dimensional external flows, boundary layers, flow separation; Compressible flow, isentropic flow, normal and oblique shocks, Prandtl-Meyer expansion fans, Fanno and Rayleigh flow; Introduction to flow instabilities (e.g., Kelvin-Helmholtz instability, Raleigh Benard convection). Prerequisite: MEGN351 (C- or better). 3 hours lecture; 3 semester hours.

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.
Equivalent with EGGN403,
(I) This course extends the subject matter of Thermodynamics I (MEGN361) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Phase equilibrium, ionization, and the thermodynamics of compressible flow (nozzles and shock) are also introduced. Concepts of the above are explored through the analysis of advanced thermodynamic systems, such as cascaded and absorption refrigeration systems, cryogenics, and advanced gas turbine and combined power cycles. Prerequisites: MEGN351 (C- or better), MEGN361 (C- or better). 3 hours lecture; 3 semester hours.

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.
(II) Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one ? semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisites: MEGN351, MEGN361. Co-requisites: MEGN471. 3 hours lecture; 1.0 hour lab; 3 semester hours.

MEGN467. HVAC AND BUILDING ENERGY SYSTEMS. 3.0 Semester Hrs.
(I) Senior year undergraduate and first year graduate course that covers the fundamentals of building energy systems, heating, ventilation, and air conditioning (HVAC) systems and the use of numerical models for heat and mass transfer to analyze and/or design different building elements. Prerequisites: MEGN351, MEGN361, MEGN471. 3 hours lecture; 3 semester hours.

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN469,CHEN469,EGGN469,MTGN469,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisites: MEGN361 or CBEN357 or MTGN351. 3 hours lecture; 3 semester hours.

MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.
Equivalent with EGGN471,
(I, II) Engineering approach to conduction, convection, and radiation, including steadystate conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. Prerequisites: MEGN351 (C- or better), MEGN361 (C- or better), and MATH307 (C- or better). 3 hours lecture; 3 semester hours.

MEGN481. MACHINE DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN411,
(I, II) In this course, students develop their knowledge of machine components and materials for the purpose of effective and efficient mechanical design. Emphasis is placed on developing analytical methods and tools that aid the decision making process. The course focuses on determination of stress, strain, and deflection for static, static multiaxial, impact, dynamic, and dynamic multiaxial loading. Students will learn about fatigue failure in mechanical design and calculate how long mechanical components are expected to last. Specific machine components covered include shafts, springs, gears, fasteners, and bearings. Prerequisites: MEGN315 (C- or better) or PHGN350 (C- or better), and MEGN424 (C- or better). Corequisite: MEGN489. 3 hours lecture; 3 semester hours.

MEGN482. MECHANICAL DESIGN USING GD&T. 3.0 Semester Hrs.
Equivalent with EGGN410,
(II) The mechanical design process can be broadly grouped into three phases: requirements and concept, design and analysis, details and drawing package. In this class students will learn concepts and techniques for the details and drawing package phase of the design process. The details of a design are critical to the success of a design project. The details include selection and implementation of a variety of mechanical components such as fasteners (threaded, keys, retaining rings), bearing and bushings. Fits and tolerances will also be covered. Statistical tolerance analysis will be used to verify that an assembly will fit together and to optimize the design. Mechanical drawings have become sophisticated communication tools that are used throughout the processes of design, manufacturing, and inspection. Mechanical drawings are interpreted either by the ANSI or ISO standard which includes Geometric Dimensioning and Tolerancing (GD&T). In this course the student will learn to create mechanical drawings that communicate all of the necessary information to manufacture the part, inspect the part, and allow the parts to be assembled successfully. Prerequisite: MEGN201. 3 hours lecture, 3 semester hours.

MEGN483. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.
Equivalent with EBGN456,
(I) We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Prerequisites: MATH111. 3 hours lecture; 3 semester hours.

MEGN486. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
(I) This course addresses the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH332 or EBGN509. 3 hours lecture; 3 semester hours.

MEGN487. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN587,
(I) This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton?s Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111. 3 hours lecture; 3 semester hours.

MEGN488. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN588,
(I) This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111. 3 hours lecture; 3 semester hours.

MEGN489. MACHINE DESIGN LAB. 1.0 Semester Hr.
(I, II) This lab course supports MEGN 481, Machine Design. This lab component includes 2-3 projects in which students work in teams during lab to solve an ill-defined engineering problem. The lab portion of the course hones students' professional communication via written deliverables intended for the general engineering client audience (professional engineering reports). The lab culminates in an oral presentation and sales pitch to the general engineering client for the purpose of moving forward with the team?s design. Corequisite: MEGN481. 3 hours lab; 1 semester hour.

MEGN493. ENGINEERING DESIGN OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with EGGN493,
(II) The application of gradient, stochastic and heuristic optimization algorithms to linear and nonlinear optimization problems in constrained and unconstrained design spaces. Students will consider problems with continuous, integer and mixed-integer variables, problems with single or multiple objectives and the task modeling design spaces and constraints. Design optimization methods are becoming of increasing importance in engineering design and offer the potential to reduce design cycle times while improving design quality by leveraging simulation and historical design data. Prerequisites: MATH213 and MATH225 (Required), CSCI260 or CSCI261 or other experience with computer programming languages (Suggested). 3 hours lecture; 3 semester hours.

MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN501. ADVANCED ENGINEERING MEASUREMENTS. 3.0 Semester Hrs.
Equivalent with EGGN501,
(I) Introduction to the fundamentals of measurements within the context of engineering systems. Topics that are covered include: errors and error analysis, modeling of measurement systems, basic electronics, noise and noise reduction, and data acquisition systems. Prerequisite: EGGN250, EENG281 or equivalent, and MATH323 or equivalent; graduate student status. 3 hours lecture, 1 hour lab; 3 semester hours.

MEGN502. ADVANCED ENGINEERING ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN502,
(I) Introduce advanced mathematical and numerical methods used to solve engineering problems. Analytic methods include series solutions, special functions, Sturm-Liouville theory, separation of variables, and integral transforms. Numerical methods for initial and boundary value problems include boundary, domain, and mixed methods, finite difference approaches for elliptic, parabolic, and hyperbolic equations, Crank-Nicolson methods, and strategies for nonlinear problems. The approaches are applied to solve typical engineering problems. Prerequisite: This is an introductory graduate class. The student must have a solid understanding of linear algebra, calculus, ordinary differential equations, and Fourier theory. 3 hours lecture.

MEGN503. GRADUATE SEMINAR. 0.0 Semester Hrs.
Equivalent with EGGN504M,
(I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today?s competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Mechanical Engineering graduate program. Prerequisite: Graduate standing. 1 hour per week; 0 semester hours. Course is repeatable, but no coursework credit is awarded.

MEGN510. SOLID MECHANICS OF MATERIALS. 3.0 Semester Hrs.
Equivalent with EGGN543,
(II) Introduction to the algebra of vectors and tensors; coordinate transformations; general theories of stress and strain; principal stresses and strains; octahedral stresses; Hooke?s Law introduction to the mathematical theory of elasticity and to energy methods; failure theories for yield and fracture. Prerequisite: CEEN311 or equivalent, MATH225 or equivalent. 3 hours lecture; 3 semester hours.

MEGN511. FATIGUE AND FRACTURE. 3.0 Semester Hrs.
Equivalent with EGGN532,MTGN545,
(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, odd numbered years.

MEGN512. ADVANCED ENGINEERING VIBRATION. 3.0 Semester Hrs.
Equivalent with EGGN546,
Vibration theory as applied to single- and multi-degree-of freedom systems. Free and forced vibrations to different types of loading-harmonic, impulse, periodic and general. Natural frequencies. Role of Damping. Importance of resonance. Modal superposition method. Prerequisite: MEGN315, 3 hours lecture; 3 semester hours.

MEGN513. KINETIC PHENOMENA IN MATERIALS. 3.0 Semester Hrs.
Equivalent with EGGN555,MLGN511,
(I) Linear irreversible thermodynamics, dorce-flux couplings, diffusion, crystalline materials, amorphous materials, defect kinetics in crystalline materials, interface kinetics, morphological evolution of interfaces, nucleation theory, crystal growth, coarsening phenomena and grain growth, solidification, spinodal decomposition. Prerequisites: MATH225: Differential equations (or equivalent), MLGN504/MTGN555/CBEN509: Thermodynamics (or its equivalent).

MEGN514. CONTINUUM MECHANICS. 3.0 Semester Hrs.
(I) This is a graduate course covering fundamentals of continuum mechanics and constitutive modeling. The goal of the course is to provide graduate students interested in fluid and solid mechanics with the foundation necessary to review and write papers in the field. Students will also gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws. The course explores six subjects: 1. Mathematical Preliminaries of Continuum Mechanics (Vectors, Tensors, Indicial Notation, Tensor Properties and Operations, Coordinate Transformations) 2. Stress (Traction, Invariants, Principal Values) 3. Motion and Deformation (Deformation Rates, Geometric Measures, Strain Tensors, Linearized Displacement Gradients) 4. Balance Laws (Conservation of Mass, Momentum, Energy) 5. Ideal Constitutive Relations (Frictionless & Linearly Viscous Fluids, Elasticity) 6. Constitutive Modeling (Formulation, Derivation, Implementation, Programming). 3 hours lecture, 3 semester hours.

MEGN515. COMPUTATIONAL MECHANICS. 3.0 Semester Hrs.
(I) A graduate course in computational mechanics with an emphasis on a studying the major numerical techniques used to solve problems that arise in mechanics and some related topical areas. Variational methods are applied throughout as a general approach in the development of many of these computational techniques. A wide range of problems are addressed in one- and two- dimensions which include linear and nonlinear elastic and elastoplastic steady state mechanics problems. Computational algorithms for time dependent problems such as transient dynamics and viscoplasticity are also addressed. In the latter part of the course an introduction to computational methods employing boundary integral equations, and particle methods for solving the mechanical behavior of multi-body systems are also given. Note all the software used in this course is written in MATLAB which has become a widely acceptable engineering programming tool. Prerequisites: MEGN312 and MEGN502. 3 lecture hours, 3 semester hours.

MEGN517. INELASTIC CONSTITUTIVE RELATIONS. 3.0 Semester Hrs.
(II) This is a graduate course on inelastic constitutive relations of solid materials. The goal of the course is to provide students working in solid mechanics and metallurgy with a foundation in theory and models of inelastic material behaviors. The behaviors we cover include plasticity, thermoelasticity, nonlinear elasticity, and phase transformations. We dive in at several length scales - crystal mechanics and phenomenological thermodynamic internal variable theory. We also discuss ties between models and state of the art experimental mechanics, including in-situ diffraction. We will cover both theory and numerical implementation strategies for the topics. Thus, students will gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws and crystal mechanics models. We will introduce many topics rather than focusing on a few such that students have a foot-in to dive deeper on their own, as they will do in the project. Prerequisites: MEGN514. 3 hours lecture, 3 semester hours.

MEGN520. BOUNDARY ELEMENT METHODS. 3.0 Semester Hrs.
Equivalent with EGGN545,
(II) Development of the fundamental theory of the boundary element method with applications in elasticity, heat transfer, diffusion, and wave propagation. Derivation of indirect and direct boundary integral equations. Introduction to other Green?s function based methods of analysis. Computational experiments in primarily two dimensions. Prerequisite: MEGN502. 3 hours lecture; 3 semester hours Spring Semester, odd numbered years.

MEGN521. INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS). 3.0 Semester Hrs.
Equivalent with EGGN535,
(I) Review of particle/rigid body dynamics, numerical DEM solution of equations of motion for a system of particles/rigid bodies, linear and nonlinear contact and impact laws dynamics, applications of DEM in mechanical engineering, materials processing and geo-mechanics. Prerequisites: CEEN311, MEGN315 and some scientific programming experience in C/C++ or Fortran. 3 hours lecture; 3 semester hours Spring semester of even numbered years.

MEGN530. BIOMEDICAL INSTRUMENTATION. 3.0 Semester Hrs.
Equivalent with BELS530,EGGN530,
The acquisition, processing, and interpretation of biological signals presents many unique challenges to the Biomedical Engineer.
This course is intended to provide students with the knowledge to understand, appreciate, and address these challenges. At the end of the semester, students should have a working knowledge of the special considerations necessary to gathering and analyzing biological signal data. Prerequisites: EGGN250 MEL I, EENG281 Introduction to Electrical Circuits, Electronics, and Power, MEGN330 Introduction to Biomedical Engineering. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN531. PROSTHETIC AND IMPLANT ENGINEERING. 3.0 Semester Hrs.
Equivalent with BELS527,EGGN527,
Prosthetics and implants for the musculoskeletal and other systems of the human body are becoming increasingly sophisticated. From simple joint replacements to myoelectric limb replacements and functional electrical stimulation, the engineering opportunities continue to expand. This course builds on musculoskeletal biomechanics and other BELS courses to provide engineering students with an introduction to prosthetics and implants for the musculoskeletal system. At the end of the semester, students should have a working knowledge of the challenges and special considerations necessary to apply engineering principles to augmentation or replacement in the musculoskeletal system. Prerequisites: Musculoskeletal Biomechanics [MEGN430], 3 hours lecture; 3 semester hours. Fall even years.

MEGN532. EXPERIMENTAL METHODS IN BIOMECHANICS. 3.0 Semester Hrs.
(I) Introduction to experimental methods in biomechanical research. Topics include experimental design, hypothesis testing, motion capture, kinematic models, ground reaction force data collection, electromyography, inverse dynamics calculations, and applications. Strong emphasis on hands-on data collection and technical presentation of results. The course will culminate in individual projects combining multiple experimental measurement techniques. Prerequisite: Graduate Student Standing. 3 hours lecture; 3.0 semester hours.

MEGN535. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Equivalent with BELS526,EGGN526,
(II) Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties and interactions with the environment to construct detailed computer models and simulations. The course will culminate in individual class projects related to each student?s individual interests. Prerequisites: MEGN315 and MEGN330. 3 hours lecture; 3 semester hours.

MEGN536. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.
Equivalent with BELS528,EGGN528,
Computational Biomechanics provides and introduction to the application of computer simulation to solve some fundamental problems in biomechanics and bioengineering. Musculoskeletal mechanics, medical image reconstruction, hard and soft tissue modeling, joint mechanics, and inter-subject variability will be considered. An emphasis will be placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of computational techniques. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is demonstrated. Prerequisite: MEGN424, MEGN330. 3 hours lecture; 3 semester hours. Fall odd years.

MEGN537. PROBABILISTIC BIOMECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN529,
(II) MEGN537. PROBABILISTIC BIOMECHANICS The course introduces the application of probabilistic analysis methods in biomechanical systems. All real engineering systems, and especially human systems, contain inherent uncertainty due to normal variations in dimensional parameters, material properties, motion profiles, and loading conditions. The purpose of this course is to examine methods for including these sources of variation in biomechanical computations. Concepts of basic probability will be reviewed and applied in the context of engineering reliability analysis. Probabilistic analysis methods will be introduced and examples specifically pertaining to musculoskeletal biomechanics will be studied. Prerequisites: MEGN436/BELS428 or MEGN536/BELS528. 3 hours lecture, 3 semester hours. Spring even years.

MEGN540. MECHATRONICS. 3.0 Semester Hrs.
Equivalent with EGGN521,
(II) A course focusing on implementation aspects of mechatronic and control systems. Significant lab component involving embedded C programming on a mechatronics teaching platform, called a "haptic paddle", a single degree-of-freedom force-feedback joystick. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

MEGN544. ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL. 3.0 Semester Hrs.
Equivalent with EGGN518,
(I) Mathematical representation of robot structures. Mechanical analysis including kinematics, dynamics, and design of robot manipulators. Representations for trajectories and path planning for robots. Fundamentals of robot control including, linear, nonlinear and force control methods. Introduction to off-line programming techniques and simulation. Prerequisite: EENG307 and MEGN441. 3 hours lecture; 3 semester hours.

MEGN545. ADVANCED ROBOT CONTROL. 3.0 Semester Hrs.
Equivalent with EGGN514,
The focus is on mobile robotic vehicles. Topics covered are: navigation, mining applications, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path planning real time obstacle avoidance. Prerequisite: EENG307. 3 hours lecture; 3 semester hours. Spring semester of odd years.

MEGN551. ADVANCED FLUID MECHANICS. 3.0 Semester Hrs.
(I) This first year graduate course covers the fundamentals of incompressible fluid mechanics with a focus on differential analysis and building a strong foundation in the prerequisite concepts required for subsequent study of computational fluid dynamics and turbulence. The course is roughly divided into four parts covering (i) the governing equations of fluid mechanics, (ii) Stokes flows and ideal-fluid flows, (iii) boundary layer flows, and (iv) hydrodynamic stability and transition to turbulence. Prerequisites: MEGN351. 3 hours lecture; 3 semester hours.

MEGN552. VISCOUS FLOW AND BOUNDARY LAYERS. 3.0 Semester Hrs.
Equivalent with EGGN552,
(I) This course establishes the theoretical underpinnings of fluid mechanics, including fluid kinematics, stress-strain relationships, and derivation of the fluid-mechanical conservation equations. These include the mass-continuity and Navier-Stokes equations as well as the multi-component energy and species-conservation equations. Fluid-mechanical boundary-layer theory is developed and applied to situations arising in chemically reacting flow applications including combustion, chemical processing, and thin-film materials processing. Prerequisite: MEGN451, or CBEN430. 3 hours lecture; 3 semester hours.

MEGN553. INTRODUCTION TO COMPUTATIONAL TECHNIQUES FOR FLUID DYNAMICS AND TRANSPORT PHENOMENA. 3.0 Semester Hrs.
Equivalent with EGGN573,
(II) Introduction to Computational Fluid Dynamics (CFD) for graduate students with no prior knowledge of this topic. Basic techniques for the numerical analysis of fluid flows. Acquisition of hands-on experience in the development of numerical algorithms and codes for the numerical modeling and simulation of flows and transport phenomena of practical and fundamental interest. Capabilities and limitations of CFD. Prerequisite: MEGN451. 3 hours lecture; 3 semester hours.

MEGN560. DESIGN AND SIMULATION OF THERMAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN570,
In this course the principles of design, modeling, analysis, and optimization of processes, devices, and systems are introduced and applied to conventional and advanced energy conversion systems. It is intended to integrate conservation principles of thermodynamics (MEGN361) with the mechanism relations of fluid mechanics (MEGN351) and heat transfer (MEGN471). The course begins with general system design approaches and requirements and proceeds with mathematical modeling, simulation, analysis, and optimization methods. The design and simulation of energy systems is inherently computational and involves modeling of thermal equipment, system simulation using performance characteristics, thermodynamic properties, mechanistic relations, and optimization (typically with economic-based objective functions). Fundamental principles for steady-state and dynamic modeling are covered. Methods for system simulation which involves predicting performance with a given design (fixed geometry) are studied. Analysis methods that include Pinch Technology, Exergy Analysis, and Thermo-economics are examined and are considered complementary to achieving optimal designs. Optimization encompasses objective function formulation, systems analytical methods, and programming techniques. System optimization of the design and operating parameters of a configuration using various objective functions are explored through case studies and problem sets. Economics and optimization for analyses and design of advanced energy systems, such as Rankine and Brayton cycle power plants, combined heat and power, refrigeration and geothermal systems, fuel cells, turbomachinery, and heat transfer equipment are a focus. 3 lecture hours; 3 credit hours.

MEGN561. ADVANCED ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.
(I) First year graduate course in engineering thermodynamics that emphasizes a greater depth of study of undergraduate subject matter and an advancement to more complex analyses and topics. The course begins with fundamental concepts, 1st and 2nd Law analyses of processes, devices, and systems and advances to equations of state, property relations, ideal and non-ideal gas mixtures, chemically reacting systems, and phase equilibrium. Historical and modern contexts on the development and advancements of thermodynamic concepts are given. Fundamental concepts are explored through the analysis of advanced thermodynamic phenomena and use of computational tools to solve more realistic problems. Prerequisites: MEGN351, MEGN361, and MEGN471. 3 hours lecture; 3 semester hours.

MEGN566. COMBUSTION. 3.0 Semester Hrs.
Equivalent with EGGN566,
(I) An introduction to combustion. Course subjects include: the development of the Chapman-Jouget solutions for deflagration and detonation, a brief review of the fundamentals of kinetics and thermochemistry, development of solutions for diffusion flames and premixed flames, discussion of flame structure, pollutant formation, and combustion in practical systems. Prerequisite: MEGN451 or CBEN430. 3 hours lecture; 3 semester hours.

MEGN567. HVAC AND BUILDING ENERGY SYSTEMS. 3.0 Semester Hrs.
(I) First or second year graduate course that covers the fundamentals of building energy systems, moist air processes, heating, ventilation, and air conditioning (HVAC) systems and the use of numerical models for heat and mass transfer to analyze advanced building technologies such as phase change materials, green roofs or cross laminated timber. Prerequisites: MEGN351, MEGN361, MEGN471. 3 hours lecture; 3 semester hours.

MEGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN569,CHEN569,EGGN569,MLGN569,MTGN569,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

MEGN570. ELECTROCHEMICAL SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I) In this course, students will gain fundamental, quantitative insight into the operation of electrochemical devices for engineering analysis across a range of length scales and applications. The course will use the development of numerical models as a lens through which to view electrochemical devices. However, the course will also deal extensively with "real world" systems and issues, including experimental characterization, system optimization and design, and the cyclical interplay between models and physical systems. The course begins by establishing the equations that govern device performance at the most fundamental level, describing chemical and electrochemical reactions, heat transfer, transport of charged and neutral species, and material properties in operating devices. Subsequently, these equations will be used to discuss and analyze engineering issues facing three basic types of electrochemical devices: fuel cells, batteries, and sensors. At each juncture will evaluate our equations to determine when simpler models may be more suitable. Throughout the semester, concepts will be applied in homework assignments, including an over-arching, semester-long project to build detailed numerical models for an application of each student's choosing. 3 hours lecture; 3 semester hours.

MEGN571. ADVANCED HEAT TRANSFER. 3.0 Semester Hrs.
Equivalent with EGGN571,
(II) An advanced course in heat transfer that supplements topics covered in MEGN471. Derivation and solution of governing heat transfer equations from conservation laws. Development of analytical and numerical models for conduction, convection, and radiation heat transfer, including transient, multidimensional, and multimode problems. Introduction to turbulence, boiling and condensation, and radiative transfer in participating media. 3 lecture hours; 3 credit hours.

MEGN583. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
(II) Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.

MEGN585. NETWORK MODELS. 3.0 Semester Hrs.
(I) We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours.

MEGN586. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
(I) We address the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours.

MEGN587. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN487,
(II) We address both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Prerequisite: MATH111. 3 hours lecture; 3 semester hours.

MEGN588. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN488,
(I) We address the formulation of integer programming models, the brand-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Prerequisite: none. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN591. ADVANCED ENGINEERING DESIGN METHODS. 3.0 Semester Hrs.
Equivalent with EGGN503,
(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions. Ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embodiment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

MEGN592. RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.
(I) The importance of understanding, assessing, communicating, and making decisions based in part upon risk, reliability, robustness, and uncertainty is rapidly increasing in a variety of industries (e.g.: petroleum, electric power production, etc.) and has been a focus of some industries for many decades (e.g.: nuclear power, aerospace, automotive, etc). This graduate class will provide the student with a technical understanding of and ability to use common risk assessment tools such as Reliability Block Diagrams (RBD), Failure Modes and Effects Analysis (FMEA), and Probabilistic Risk Assessment (PRA); and new tools being developed in universities including Function Failure Design Methods (FFDM), Function Failure Identification and Propagation (FFIP), and Uncoupled Failure Flow State Reasoning (UFFSR) among others. Students will also be provided with a high-level overview of what risk really means and how to contextualize risk information. Methods of communicating and making decisions based in part upon risk information will be discussed. 3 hours lecture, 3 semester hours.

MEGN593. ENGINEERING DESIGN OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with EGGN593,
The application of gradient, stochastic and heuristic optmization algorithms to linear and nonlinear optimization problems in constrained and unconstrained design spaces. Students will consider problems in constrained and unconstrained design spaces. Students will consider problems with continuous, integer and mixed-integer variables, problems with single or multiple objectives and the task modeling design spaces and constraints. Design optimization methods are becoming of increasing importance in engineering design and offer the potential to reduce design cycle times while improving design quality by leveraging simulation and historical design data. Prerequisites: Experience wiht computer programming languages, graduate or senior standing. 3 hours lecture; 3 semester hours.

MEGN598. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN686. ADVANCED LINEAR OPTIMIZATION. 3.0 Semester Hrs.
(II) As an advanced course in optimization, we expand upon topics in linear programming: advanced formulation, the dual simplex method, the interior point method, algorithmic tuning for linear programs (including numerical stability considerations), column generation, and Dantzig-Wolfe decomposition. Time permitting, dynamic programming is introduced. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Offered every other year. Prerequisite: MEGN586. 3 hours lecture; 3 semester hours.

MEGN688. ADVANCED INTEGER OPTIMIZATION. 3.0 Semester Hrs.
(II) As an advanced course in optimization, we expand upon topics in integer programming: advanced formulation, strong integer programming formulations (e.g., symmetry elimination, variable elimination, persistence), in-depth mixed integer programming cuts, rounding heuristics, constraint programming, and decompositions. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Prerequisite: MEGN588. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.

MEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with EGGN707M,
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

METALLURGICAL AND MATERIALS ENGINEERING (MTGN)

MTGN198. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN199. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN202. ENGINEERED MATERIALS. 3.0 Semester Hrs.
Equivalent with SYGN202,
(I, II, S) Introduction to the Metallurgical and Materials Engineering paradigm: processing, structure, and properties. The course will relate technologically significant processing procedures to resultant structures. The material structure will be examined to determine its effect upon material properties. Students will study materials engineering methodologies and learn terminology. Prerequisites: CHGN122 or CHGN125, MATH112, and PHGN100. 3 hours lecture; 3 semester hours.

MTGN211. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
(II) Principles of atomic bonding, crystallography, and amorphous structures. ii) Symmetry relationships to material properties. iii) Atomic structure determination through diffraction techniques. Prerequisite: MTGN202. Corequisite: PHGN200. 3 hours lecture; 3 semester hours.

MTGN251. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
(I) Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models and thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of binary alloys in the solid state, defect equilibrium, and interactions. Prerequisites: MATH112, CHGN122 or CHGN125, and PHGN100. 3 hours lecture; 3 semester hours.

MTGN272. MME FIELD SESSION. 3.0 Semester Hrs.
(S) Introduction to the field of Metallurgical and Materials Engineering. Overview of opportunities, expectations, and practices within the MME department and the broader materials community. Introduction to bonding, crystal and grain structure, application space, and Structure-Property-Processing relationships. Laboratory projects and plant visits. Prerequisites: MATH112, PHGN100. 9 hours lab; 3 semester hours.

MTGN281. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 2.0 Semester Hrs.
(II) Review of the concepts of chemical equilibrium and derivation of the Gibbs phase rule. Application of the Gibbs phase rule to interpreting one, two and three component phase equilibrium diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisites: MTGN202, and MTGN251 or MTGN351. 2 hours lecture; 2 semester hours.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN298. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN299. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN300. FOUNDRY METALLURGY. 2.0 Semester Hrs.
(II) Design and metallurgical aspects of casting, patterns, molding materials and processes, solidification processes, risers and gating concepts, casting defects and inspection, melting practice, cast alloy selection. Corequisite: MTGN300L. 2 hours lecture; 2 semester hours.

MTGN300L. FOUNDRY METALLURGY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN302,
(II) Experiments in the foundry designed to supplement the lectures of MTGN300. Corequisite: MTGN300. 3 hours lab; 1 semester hour.

MTGN311. STRUCTURE OF MATERIALS. 3.0 Semester Hrs.
(I) Principles of crystallography and crystal chemistry. Characterization of crystalline materials using X-ray diffraction techniques. Applications to include compound identification, lattice parameter measurement, orientation of single crystals, and crystal structure determination. Prerequisites: PHGN200 and MTGN202. Co-requisite: MTGN311L. 3 hours lecture; 3 semester hours.

MTGN311L. STRUCTURE OF MATERIALS LABORATORY. 1.0 Semester Hr.
(I) (WI) Experiments in structure of materials to supplement the lectures of MTGN311. Co-requisite: MTGN311. 3 hours lab; 1 semester hour.

MTGN314. PROPERTIES AND PROCESSING OF CERAMICS. 2.0 Semester Hrs.
(I) Application of engineering principles and fundamental structure-processing-property relationship to inorganic non-metallic materials. Emergence of macroscopic characteristics and functional properties from bonding, structure, symmetry, and defects. Applications of basic thermodynamic and kinetic principles to powder-based processing. Corequisites: MTGN314L, MTGN202, and MTGN251 or MTGN351. 2 hours lecture; 2 semester hours.

MTGN314L. PROPERTIES AND PROCESSING OF CERAMICS LABORATORY. 1.0 Semester Hr.
(I) Laboratory for MTGN314. Corequisite: MTGN314. 3 hours lab; 1 semester hour.

MTGN315. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
(II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing and microstructure on the electrical properties. Functions, performance requirements and testing methods of material for each type of circuit component. General topics covered are conductors, resistors, insulators, capacitors, energy converters, magnetic materials and integrated circuits. Prerequisite: PHGN200. Corequisite: MTGN211 or MTGN311. 3 hours lecture; 3 semester hours.

MTGN334. CHEMICAL PROCESSING OF MATERIALS. 3.0 Semester Hrs.
(II) Development and application of fundamental principles related to the processing of metals and materials by thermochemical and aqueous and fused salt electrochemical/chemical routes. The course material is presented within the framework of a formalism that examines the physical chemistry, thermodynamics, reaction mechanisms and kinetics inherent to a wide selection of chemical processing systems. The general formalism provides for a transferable knowledge-base to other systems not specifically covered in the course. Prerequisites: MTGN272, MTGN351, and CEEN267 or EDNS251 or EDNS261 or EDNS262 or EDNS264 or EDNS269. Corequisite: MTGN334L. 3 hours lecture, 3 semester hours.

MTGN334L. CHEMICAL PROCESSING OF MATERIALS LABORATORY. 1.0 Semester Hr.
(II) Experiments in chemical processing of materials to supplement the lectures of MTGN334. Corequisite: MTGN334. 3 hours lab; 1 semester hour.

MTGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. 1 to 3 semester hours. Cooperative education credit does not count toward graduation except under special conditions. Repeatable.

MTGN348. MICROSTRUCTURAL DEVELOPMENT. 3.0 Semester Hrs.
(II) An introduction to the relationships between microstructure and properties of materials, with emphasis on metallic and ceramic systems; Fundamentals of imperfections in crystalline materials on material behavior; recrystallization and grain growth; strengthening mechanisms: grain refinement, solid solution strengthening, precipitation strengthening, and microstructural strengthening; and phase transformations. Prerequisites: MTGN211 or MTGN311, and MTGN251 or MTGN351. Corequisites: MTGN281 or MTGN381, and MTGN348L. 3 hours lecture, 3 semester hours.

MTGN348L. MICROSTRUCTURAL DEVELOPMENT LABORATORY. 1.0 Semester Hr.
(II) Experiments in microstructural development of materials to supplement the lectures of MTGN348. Corequisite: MTGN348. 3 hours lab; 1 semester hour.

MTGN350. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.
(I) Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments. 3 hours lecture, 3 semester hours.

MTGN351. METALLURGICAL AND MATERIALS THERMODYNAMICS. 3.0 Semester Hrs.
(I) Applications of thermodynamics in extractive and physical metallurgy and materials science. Thermodynamics of solutions including solution models, calculation of activities from phase diagrams, and measurements of thermodynamic properties of alloys and slags. Reaction equilibria with examples in alloy systems and slags. Phase stability analysis. Thermodynamic properties of phase diagrams in material systems, defect equilibrium and interactions. Prerequisite: CHGN209 or CBEN210. 3 hours lecture; 3 semester hours.

MTGN352. METALLURGICAL AND MATERIALS KINETICS. 3.0 Semester Hrs.
(I) Introduction to reaction kinetics: chemical kinetics, atomic and molecular diffusion, surface thermodynamics and kinetics of interfaces and nucleation-and-growth. Applications to materials processing and performance aspects associated with gas/solid reactions, precipitation and dissolution behavior, oxidation and corrosion, purification of semiconductors, carburizing of steel, formation of p-n junctions and other important materials systems. Prerequisite: MTGN272. Corequisite: MTGN251 or MTGN351. 3 hours lecture; 3 semester hours.

MTGN381. INTRODUCTION TO PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 2.0 Semester Hrs.
(I) Review of the concepts of chemical equilibrium and derivation of the Gibbs phase rule. Application of the Gibbs phase rule to interpreting one, two and three component phase equilibrium diagrams. Application to alloy and ceramic materials systems. Emphasis on the evolution of phases and their amounts and the resulting microstructural development. Prerequisite/Co-requisite: MTGN351. 2 hours lecture; 2 semester hours.

MTGN398. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 1-3 Semester Hr.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN399. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Choice of problem is arranged between student and a specific department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit.

MTGN403. SENIOR THESIS. 3.0 Semester Hrs.
(I, II,S) Two-semester individual research under the direction of members of the MME faculty. Work may include library and laboratory research on topics of relevance. Oral presentation will be given at the end of the second semester and written thesis submitted to committee of evaluation. 3 hours research; 3 semester hours.

MTGN407. STEEL BAR MANUFACTURING. 1.0 Semester Hr.
(I) Facilities and metallurgical principles for manufacturing carbon and low alloy steel bars that are further transformed into high performance parts. Discussion of steel melting, ladle refining, casting, hot rolling, heat treatment, final processing, inspection and testing methods. Implications of process design and control on chemical uniformity, macrostructure, microstructure, internal quality, surface quality, mechanical properties and residual stresses. Review of customer processes and requirements for manufacturing parts from bars by hot or cold forging, machining, surface treating, and heat treating. Applications include crankshafts, gears, axles, drive shafts, springs, bearings, rails, line pipe, oil well casing, etc. Prerequisite: MTGN348. 1 hour lecture; 1.0 semester hour.

MTGN412. CERAMIC ENGINEERING. 3.0 Semester Hrs.
(I) Application of engineering principles to nonmetallic and ceramic materials. Processing of raw materials and production of ceramic bodies, glazes, glasses, enamels, and cements. Firing processes and reactions in glass bonded as well as mechanically bonded systems. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN414. ADVANCED PROCESSING AND SINTERING OF CERAMICS. 3.0 Semester Hrs.
(II) Principles of ceramics processing and the relationship between processing and microstructure, with a focus on advanced microstructural control using thermal and athermal energy input in single and multiphase systems. Principles will be illustrated using case studies on specific ceramic materials. A project to design a ceramic fabrication process is required. Prerequisite: MTGN314. 3 hours lecture; 3 semester hours.

MTGN415. ELECTRICAL PROPERTIES AND APPLICATIONS OF MATERIALS. 3.0 Semester Hrs.
(II) Survey of the electrical properties of materials, and the applications of materials as electrical circuit components. The effects of chemistry, processing and microstructure on the electrical properties. Functions, performance requirements and testing methods of materials for each type of circuit component. General topics covered are conductors, resistors, insulators, capacitors, energy converters, magnetic materials and integrated circuits. Prerequisites: PHGN200 and MTGN311. 3 hours lecture; 3 semester hours.

MTGN419. NON-CRYSTALLINE MATERIALS. 3.0 Semester Hrs.
(I, II, S) Introduction to the principles of glass science and engineering and non-crystalline materials in general. Glass formation, structure, crystallization and properties will be covered, along with a survey of commercial glass compositions, manufacturing processes and applications. Prerequisites: MTGN211 or MTGN311, and MTGN412 or MTGN314. 3 hours lecture; 3 semester hours.

MTGN429. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
(I) Examination of the interface between metallurgical process engineering and environmental engineering. Wastes, effluents and their point sources in metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of metallurgical unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for selected examples. Fundamentals and applications receive equal coverage. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN430. PHYSICAL CHEMISTRY OF IRON AND STEELMAKING. 3.0 Semester Hrs.
(I, II, S) Physical chemistry principles of blast furnace and direct reduction production of iron and refining of iron to steel. Discussion of raw materials, productivity, impurity removal, deoxidation, alloy additions, and ladle metallurgy. Offered every other year. Prerequisites: MTGN334, and MTGN251 or MTGN351. 3 hours lecture; 3 semester hours.

MTGN431. HYDRO- AND ELECTRO-METALLURGY. 3.0 Semester Hrs.
(I, II, S) Physicochemical principles associated with the extraction and refining of metals by hydro- and electrometallurgical techniques. Discussion of unit processes in hydrometallurgy, electrowinning, and electrorefining. Analysis of integrated flowsheets for the recovery of nonferrous metals. Offered every other year. Prerequisites: MTGN334, MTGN352, and MTGN351 or MTGN251. Corequisite: MTGN461. 3 hours lecture; 3 semester hours.

MTGN432. PYROMETALLURGY. 3.0 Semester Hrs.
(II) Extraction and refining of metals including emerging practices. Modifications driven by environmental regulations and by energy minimization. Analysis and design of processes and the impact of economic constraints. Prerequisite: MTGN334. 3 hours lecture; 3 semester hours.

MTGN442. ENGINEERING ALLOYS. 3.0 Semester Hrs.
(I, II, S) This course is intended to be an important component of the physical metallurgy sequence, to reinforce and integrate principles from earlier courses, and enhance the breadth and depth of understanding of concepts in a wide variety of alloy systems. Metallic systems considered include iron and steels, copper, aluminum, titanium, superalloys, etc. Phase stability, microstructural evolution and structure/property relationships are emphasized. Offered every other year. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN445. MECHANICAL PROPERTIES OF MATERIALS. 3.0 Semester Hrs.
(I) Mechanical properties and relationships. Plastic deformation of crystalline materials. Relationships of microstructures to mechanical strength. Fracture, creep, and fatigue. Prerequisite: MTGN348. Corequisite: MTGN445L. 3 hours lecture, 3 semester hours.

MTGN445L. MECHANICAL PROPERTIES OF MATERIALS LABORATORY. 1.0 Semester Hr.
(I) Laboratory sessions devoted to advanced mechanical-testing techniques to illustrate the application of the fundamentals presented in the lectures of MTGN445. Corequisite: MTGN445. 3 hours lab; 1 semester hour.

MTGN450. STATISTICAL PROCESS CONTROL AND DESIGN OF EXPERIMENTS. 3.0 Semester Hrs.
(I) Introduction to statistical process control, process capability analysis and experimental design techniques. Statistical process control theory and techniques developed and applied to control charts for variables and attributes involved in process control and evaluation. Process capability concepts developed and applied to the evaluation of manufacturing processes. Theory of designed experiments developed and applied to full factorial experiments, fractional factorial experiments, screening experiments, multilevel experiments and mixture experiments. Analysis of designed experiments by graphical and statistical techniques. Introduction to computer software for statistical process control and for the design and analysis of experiments. Prerequisite: none. 3 hours lecture, 3 semester hours.

MTGN451. CORROSION ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Principles of electrochemistry. Corrosion mechanisms. Methods of corrosion control including cathodic and anodic protection and coatings. Examples, from various industries, of corrosion problems and solutions. Prerequisite: MTGN251 or MTGN351. 3 hours lecture; 3 semester hours.

MTGN456. ELECTRON MICROSCOPY. 2.0 Semester Hrs.
(I, II, S) Introduction to electron optics and the design and application of transmission and scanning electron microscopes. Interpretation of images produced by various contrast mechanisms. Electron diffraction analysis and the indexing of electron diffraction patterns. Prerequisites: MTGN211 or MTGN311. Corequisite: MTGN456L. 2 hours lecture; 2 semester hours.

MTGN456L. ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN458,
(I, II, S) Laboratory exercises to illustrate specimen preparation techniques, microscope operation, and the interpretation of images produced from a variety of specimens, and to supplement the lectures in MTGN456. Corequisite: MTGN456. 3 hours lab; 1 semester hour.

MTGN461. TRANSPORT PHENOMENA AND REACTOR DESIGN FOR METALLURGICAL AND MATERIALS ENGINEERS. 3.0 Semester Hrs.
(I) Introduction to the conserved-quantities: momentum, heat, and mass transfer, and application of chemical kinetics to elementary reactor-design. Examples from materials processing and process metallurgy. Molecular transport properties: viscosity, thermal conductivity, and mass diffusivity of materials encountered during processing operations. Uni-directional transport: problem formulation based on the required balance of the conserved- quantity applied to a control-volume. Prediction of velocity, temperature and concentration profiles. Equations of change: continuity, motion, and energy. Transport with two independent variables (unsteady-state behavior). Interphase transport: dimensionless correlations friction factor, heat, and mass transfer coefficients. Elementary concepts of radiation heat-transfer. Flow behavior in packed beds. Design equations for: continuous- flow/batch reactors with uniform dispersion and plug flow reactors. Digital computer methods for the design of metallurgical systems. Prerequisite: MATH225, MTGN334, and MTGN352. 3 hours lecture; 3 semester hours.

MTGN461L. TRANSPORT PHENOMENA AND REACTOR DESIGN LABORATORY. 1.0 Semester Hr.
(II) Experiments in transport phenomena and reactor design to supplement the lectures of MTGN461. Co-requisite: MTGN461. 3 hours lab; 1 semester hour.

MTGN462. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
(I) This course will examine, using case studies, how industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisites: CEEN301, CEEN302, and CHGN403. 3 hours lecture; 3 semester hours.

MTGN463. POLYMER ENGINEERING. 3.0 Semester Hrs.
(I, II, S) An introduction to the structure and properties of polymeric materials, their deformation and failure mechanisms, and the design and fabrication of polymeric end items. The molecular and crystallographic structures of polymers will be developed and related to the elastic, viscoelastic, yield, and fracture properties of polymer solids and reinforced polymer composites. Emphasis will be placed on forming and joining techniques for end item fabrication including: extrusion, injection molding, reaction injection molding, thermoforming, and blow molding. The design of end items will be considered in relation to: materials selection, manufacturing engineering, properties and applications. Offered every other year. 3 hours lecture; 3 semester hours.

MTGN464. FORGING AND FORMING. 2.0 Semester Hrs.
(II) Introduction to plasticity. Survey and analysis of working operations of forging, extrusion, rolling, wire drawing and sheet-metal forming. Metallurgical structure evolution during working. Prerequisites: CEEN311 or MEGN312, and MTGN348 or MEGN350. Corequisite: MTGN464L. 2 hours lecture; 2 semester hours.

MTGN464L. FORGING AND FORMING LABORATORY. 1.0 Semester Hr.
(II) Experiments in forging and forming to supplement the lectures of MTGN464. Corequisite: MTGN464. 3 hours lab; 1 semester hour.

MTGN465. MECHANICAL PROPERTIES OF CERAMICS. 3.0 Semester Hrs.
(II) Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high-temperature mechanical behavior, including fracture and creep deformation. Offered every other year. Prerequisites: MTGN211 or MTGN311, and MTGN314 or MTGN412. 3 hours lecture; 3 semester hours.

MTGN466. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 3.0 Semester Hrs.
(II) (WI) Application of fundamental materials-engineering principles to the design of systems for extraction and synthesis, and to the selection of materials. Systems covered range from those used for metallurgical processing to those used for processing of emergent materials. Microstructural design, characterization and properties evaluation provide the basis for linking synthesis to applications. Selection criteria tied to specific requirements such as corrosion resistance, wear and abrasion resistance, high temperature service, cryogenic service, vacuum systems, automotive systems, electronic and optical systems, high strength/weight ratios, recycling, economics and safety issues. Materials investigated include mature and emergent metallic, ceramic and composite systems used in the manufacturing and fabrication industries. Student-team designactivities including oral- and written? reports. Prerequisite: MTGN351, MTGN352, MTGN445 and MTGN461. 1 hour lecture, 6 hours lab; 3 semester hours.

MTGN467. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
(I) Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. Prerequisite: MTGN348. Corequisites: MTGN461, MTGN445. 1 hour lecture, 3 hours lab; 2 semester hours.

MTGN468. MATERIALS DESIGN: SYNTHESIS, CHARACTERIZATION AND SELECTION. 2.0 Semester Hrs.
(II) Application of fundamental materials engineering principles to the design of systems, processes, and/or components for extraction, synthesis, operation and/or selection of materials in open-ended projects with realistic constraints. Project topics range from processes used for metallurgical processing and extraction to design and development of emergent materials to process/component analysis and (re)design. Chemical and microstructural characterization and property measurements provide the basis for linking synthesis to application and/or process to product. Selection criteria tied to specific requirements drive design under realistic constraints that include an appropriate mix of technical, economic, safety, and other considerations. Activities are carried out in teams in collaboration with project sponsors/clients. Prerequisite: MTGN352. Corequisites: MTGN348, MTGN334. 1 hour lecture, 3 hours lab; 2 semester hours.

MTGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CHEN469,EGGN469,
(I) Fuel cells provide one of the most efficient means for converting the chemical energy stored in a fuel to electrical energy. Fuel cells offer improved energy efficiency and reduced pollution compared to heat engines. While composed of no (or very few) moving parts, a complete fuel cell system amounts to a small chemical plant for the production of power. This course introduces students to the fundamental aspects of fuel cell systems, with emphasis placed on proton exchange membrane (PEM) and solid oxide fuel cells (SOFC). Students will learn the basic principles of electrochemical energy conversion while being exposed to relevant topics in materials science, thermodynamics, and fluid mechanics. Offered every other year. Prerequisites: PHGN200, MATH315, and MTGN251 or MTGN351 or CHGN209 or CHGN210 or MEGN361. 3 hours lecture; 3 semester hours.

MTGN472. BIOMATERIALS I. 3.0 Semester Hrs.
(I) This course introduces biomaterials by combining materials engineering principles with understanding of aspects of molecular and cellular biology so that students learn how materials interact with biological systems, particularly for medical use. The course is organized around four main topics: 1) fundamental properties of biomaterials; 2) fundamental concepts in biology relevant to biomaterials; 3) interactions of physiological systems with biomaterials, and 4) processing of biopolymers, bioceramics and glasses, biometals and composites. Key topics covered include processing of materials to achieve specific biological responses, surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions; biofilms and biomaterials degradation; and clinical applications of biomaterials. Offered every other year. Prerequisite: MTGN202. 3 hours lecture; 3 semester hours.

MTGN475. METALLURGY OF WELDING. 2.0 Semester Hrs.
(I, II, S) Introduction to welding processes; thermal aspects; selection of filler metals; stresses; stress relief and annealing; pre- and postweld heat treating; weld defects; welding ferrous and nonferrous alloys; weld metal phase transformations; metallurgical evaluation of resulting weld microstructures and properties; and welding tests. Offered every other year. Prerequisite: MTGN348. Corequisite: MTGN475L. 2 hours lecture; 2 semester hours.

MTGN475L. METALLURGY OF WELDING LABORATORY. 1.0 Semester Hr.
Equivalent with MTGN477,
(I, II, S) Experiments designed to supplement the lectures in MTGN475. Offered every other year. Corequisite: MTGN475. 3 hours lab; 1 semester hour.

MTGN497. SUMMER PROGRAMS. 0.0 Semester Hrs.
(S) Summer registration. Repeatable.

MTGN498. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 3.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). The course topic is generally offered only once. Prerequisite: none. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN499. INDEPENDENT STUDY. 1-3 Semester Hr.
(I, II, S) Independent advanced-work leading to a comprehensive report. This work may take the form of conferences, library, and laboratory work. Selection of problem is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic; Independent Study Form must be completed and submitted to Registrar. 1 to 3 semester hours. Repeatable for credit to a maximum of 6 hours.

MTGN501. MME GRADUATE SEMINAR. 0.5 Semester Hrs.
(I, II) All full-time MME graduate students must attend the Metallurgical and Materials Engineering seminar. Students must take the Graduate Seminar course every semester that they are enrolled at CSM. At the end of each semester, students are assigned either a satisfactory or unsatisfactory progress grade, based on attendance, until the final semester of the student's degree program, when a letter grade is assigned based on all prior semesters' attendance grades. As a result, while these courses are taken each year, only a maximum of 1.0 hours total of course credit is conferred. Students who have official part-time status are not required to sign up for Graduate Seminar. Attendance of other seminars outside MME can substitute for seminar attendance in MME following course instructor approval. 1 hour lecture; 0.5 hours. Repeatable up to 1 hour.

MTGN505. CRYSTALLOGRAPHY AND DIFFRACTION. 3.0 Semester Hrs.
(I) Introduction to point symmetry operations, crystal systems, Bravais lattices, point groups, space groups, Laue classes, stereographic projections, reciprocal lattice and Ewald sphere constructions, the new International Tables for Crystallography, and, finally, how certain properties correlate with symmetry. Subsequent to the crystallography portion, the course will move into the area of diffraction and will consider the primary diffraction techniques (x-rays, electrons and neutrons) used to determine the crystal structure of materials. Other applications of diffraction such as texture and residual stress will also be considered. Prerequisites: Graduate or Senior in good standing. 3 hours lecture, 3 semester hours.

MTGN511. SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS. 1-3 Semester Hr.
(I) Independent advanced work, not leading to a thesis. This may take the form of conferences, library, and laboratory work. Selection of assignment is arranged between student and a specific Department faculty-member. Prerequisite: Selection of topic. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN512. SPECIAL METALLURGICAL AND MATERIALS ENGINEERING PROBLEMS. 1-3 Semester Hr.
(II) Continuation of MTGN511. Prerequisite: Selection of topic. 1 to 3 semester hours. Repeatable for credit under different titles.

MTGN514. DEFECT CHEMISTRY AND TRANSPORT PROCESSES IN CERAMIC SYSTEMS. 3.0 Semester Hrs.
(I) Ceramic materials science in the area of structural imperfections, their chemistry, and their relation to mass and charge transport; defects and diffusion, sintering, and grain growth with particular emphasis on the relation of fundamental transport phenomena to sintering and microstructure development and control. Prerequisites: DCGN209 or MTGN351; MTGN311. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN516. MICROSTRUCTURE OF CERAMIC SYSTEMS. 3.0 Semester Hrs.
(II) Analysis of the chemical and physical processes controlling microstructure development in ceramic systems. Development of the glassy phase in ceramic systems and the resulting properties. Relationship of microstructure to chemical, electrical, and mechanical properties of ceramics. Application to strengthening and toughening in ceramic composite system. Prerequisite: Graduate status. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN517. REFRACTORIES. 3.0 Semester Hrs.
(I) The manufacture, testing, and use of basic, neutral, acid, and specialty refractories are presented. Special emphasis is placed on the relationship between physical properties of the various refractories and their uses in the metallurgical industry. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN518. PHASE EQUILIBRIA IN CERAMIC SYSTEMS. 3.0 Semester Hrs.
(II) Application of one to four component oxide diagrams to ceramic engineering problems. Emphasis on refractories and glasses and their interaction with metallic systems. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN523. APPLIED SURFACE AND SOLUTION CHEMISTRY. 3.0 Semester Hrs.
(II) Solution and surface chemistry of importance in mineral and metallurgical operations. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN526. GEL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the science and technology of particulate and polymeric gels, emphasizing inorganic systems. Interparticle forces. Aggregation, network formation, percolation, and the gel transition. Gel structure, rheology, and mechanical properties. Application to solid-liquid separation operations (filtration, centrifugation, sedimentation) and to ceramics processing. Prerequisite: Graduate Status. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN527. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
(II) Industrial case-studies, on the application of engineering principles to minimize waste formation and to meet solid waste recycling challenges. Proven and emerging solutions to solid waste environmental problems, especially those associated with metals. Prerequisites: ESGN500 and ESGN504. 3 hours lecture; 3 semester hours.

MTGN528. EXTRACTIVE METALLURGY OF COPPER, GOLD AND SILVER. 3.0 Semester Hrs.
Practical applications of fundamentals of chemical-processing-of-materials to the extraction of gold, silver and copper. Topics covered include: History; Ore deposits and mineralogy; Process Selection; Hydrometallurgy and leaching; Oxidation pretreatment; Purification and recovery; Refinement; Waste treatment; and Industrial examples. Prerequisites: Graduate or Senior in good-standing. 3 hours lecture, 3 semester hours.

MTGN529. METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
(I) Effluents, wastes, and their point sources associated with metallurgical processes, such as mineral concentration and values extraction? providing for an interface between metallurgical process engineering and the environmental engineering areas. Fundamentals of metallurgical unit operations and unit processes, applied to waste and effluents control, recycling, and waste disposal. Examples which incorporate engineering design and cost components are included. Prerequisites: MTGN334. 3 hours lecture; 3 semester hours.

MTGN530. ADVANCED IRON AND STEELMAKING. 3.0 Semester Hrs.
(I) Physicochemical principles of gas-slag-metal reactions applied to the reduction of iron ore concentrates and to the refining of liquid iron to steel. The role of these reactions in reactor design?blast furnace and direct iron smelting furnace, pneumatic steelmaking furnace, refining slags, deoxidation and degassing, ladle metallurgy, alloying, and continuous casting of steel. Prerequisite: DCGN209 or MTGN351. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN531. THERMODYNAMICS OF METALLURGICAL AND MATERIALS PROCESSING. 3.0 Semester Hrs.
(I) Application of thermodynamics to the processing of metals and materials, with emphasis on the use of thermodynamics in the development and optimization of processing systems. Focus areas will include entropy and enthalpy, reaction equilibrium, solution thermodynamics, methods for analysis and correlation of thermodynamics data, thermodynamic analysis of phase diagrams, thermodynamics of surfaces, thermodynamics of defect structures, and irreversible thermodynamics. Attention will be given to experimental methods for the measurement of thermodynamic quantities. Prerequisite: MTGN351. 3 hours lecture; 3 semester hours.

MTGN532. PARTICULATE MATERIAL PROCESSING I - COMMINUTION AND PHYSICAL SEPARATIONS. 3.0 Semester Hrs.
An introduction to the fundamental principles and design criteria for the selection and use of standard mineral processing unit operations in comminution and physical separation. Topics covered include: crushing (jaw, cone, gyratory), grinding (ball, pebble, rod, SAG, HPGR), screening, thickening, sedimentation, filtration and hydrocyclones. Two standard mineral processing plant-design simulation software (MinOCad and JK SimMet) are used in the course. Prerequisites: Graduate or Senior in good- standing. 3 hours lecture, 3 semester hours.

MTGN533. PARTICULATE MATERIAL PROCESSING II - APPLIED SEPARATIONS. 3.0 Semester Hrs.
An introduction to the fundamental principles and design criteria for the selection and use of standard mineral processing unit operations in applied separations. Topics covered include: photometric ore sorting, magnetic separation, dense media separation, gravity separation, electrostatic separation and flotation (surface chemistry, reagents selection, laboratory testing procedures, design and simulation). Two standard mineral processing plant-design simulation software (MinOCad and JK SimMet) are used in the course. Graduate or Senior in good-standing. 3 hours lecture, 3 semester hours.

MTGN534. CASE STUDIES IN PROCESS DEVELOPMENT. 3.0 Semester Hrs.
A study of the steps required for development of a mineral recovery process. Technical, economic, and human factors involved in bringing a process concept into commercial production. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN535. PYROMETALLURGICAL PROCESSES. 3.0 Semester Hrs.
(II) Detailed study of a selected few processes, illustrating the application of the principles of physical chemistry (both thermodynamics and kinetics) and chemical engineering (heat and mass transfer, fluid flow, plant design, fuel technology, etc.) to process development. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN536. OPTIMIZATION AND CONTROL OF METALLURGICAL SYSTEMS. 3.0 Semester Hrs.
Application of modern optimization and control theory to the analysis of specific systems in extractive metallurgy and mineral processing. Mathematical modeling, linear control analysis, dynamic response, and indirect optimum seeking techniques applied to the process analysis of grinding, screening, filtration, leaching, precipitation of metals from solution, and blast furnace reduction of metals. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN537. ELECTROMETALLURGY. 3.0 Semester Hrs.
(II) Electrochemical nature of metallurgical processes. Kinetics of electrode reactions. Electrochemical oxidation and reduction. Complex electrode reactions. Mixed potential systems. Cell design and optimization of electrometallurgical processes. Batteries and fuel cells. Some aspects of corrosion. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN538. HYDROMETALLURGY. 3.0 Semester Hrs.
(II) Kinetics of liquid-solid reactions. Theory of uniformly accessible surfaces. Hydrometallurgy of sulfide and oxides. Cementation and hydrogen reduction. Ion exchange and solvent extraction. Physicochemical phenomena at high pressures. Microbiological metallurgy. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN539. PRINCIPLES OF MATERIALS PROCESSING REACTOR DESIGN. 3.0 Semester Hrs.
(II) Review of reactor types and idealized design equations for isothermal conditions. Residence time functions for nonreacting and reacting species and its relevance to process control. Selection of reactor type for a given application. Reversible and irreversible reactions in CSTR?s under nonisothermal conditions. Heat and mass transfer considerations and kinetics of gas-solid reactions applied to fluo-solids type reactors. Reactions in packed beds. Scale up and design of experiments. Brief introduction into drying, crystallization, and bacterial processes. Examples will be taken from current metallurgical practice. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN541. INTRODUCTORY PHYSICS OF METALS. 3.0 Semester Hrs.
(I) Electron theory of metals. Classical and quantum-mechanical free electron theory. Electrical and thermal conductivity, thermo electric effects, theory of magnetism, specific heat, diffusion, and reaction rates. Prerequisite: MTGN445. 3 hours lecture; 3 semester hours.

MTGN542. ALLOYING THEORY, STRUCTURE, AND PHASE STABILITY. 3.0 Semester Hrs.
(II) Empirical rules and theories relating to alloy formation. Various alloy phases and constituents which result when metals are alloyed and examined in detail. Current information on solid solutions, intermetallic compounds, eutectics, liquid immiscibility. Prerequisite: MTGN445 or none. 3 hours lecture; 3 semester hours.

MTGN543. THEORY OF DISLOCATIONS. 3.0 Semester Hrs.
(I) Stress field around dislocation, forces on dislocations, dislocation reactions, dislocation multiplication, image forces, interaction with point defects, interpretation of macroscopic behavior in light of dislocation mechanisms. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN544. FORGING AND DEFORMATION MODELING. 3.0 Semester Hrs.
(I) Examination of the forging process for the fabrication of metal components. Techniques used to model deformation processes including slab equilibrium, slip line, upper bound and finite element methods. Application of these techniques to specific aspects of forging and metal forming processes. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN545. FATIGUE AND FRACTURE. 3.0 Semester Hrs.
(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN546. CREEP AND HIGH TEMPERATURE MATERIALS. 3.0 Semester Hrs.
(II) Mathematical description of creep process. Mathematical methods of extrapolation of creep data. Micromechanisms of creep deformation, including dislocation glide and grain boundary sliding. Study of various high temperature materials, including iron, nickel, and cobalt base alloys and refractory metals, and ceramics. Emphasis on phase transformations and microstructure-property relationships. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN547. PHASE EQUILIBRIA IN MATERIALS SYSTEMS. 3.0 Semester Hrs.
(I) Phase equilibria of uniary, binary, ternary, and multicomponent systems, microstructure interpretation, pressure-temperature diagrams, determination of phase diagrams. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN548. TRANSFORMATIONS IN METALS. 3.0 Semester Hrs.
(I) Surface and interfacial phenomena, order of transformation, grain growth, recovery, recrystallization, solidification, phase transformation in solids, precipitation hardening, spinoidal decomposition, martensitic transformation, gas metal reactions. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN549. CURRENT DEVELOPMENTS IN FERROUS ALLOYS. 3.0 Semester Hrs.
(I) Development and review of solid state transformations and strengthening mechanisms in ferrous alloys. Application of these principles to the development of new alloys and processes such as high strength low alloy steels, high temperature alloys, maraging steels, and case hardening processes. Prerequisite: MTGN348. 3 hours lecture; 3 semester hours.

MTGN551. ADVANCED CORROSION ENGINEERING. 3.0 Semester Hrs.
(I) Advanced topics in corrosion engineering. Case studies and industrial application. Special forms of corrosion. Advanced measurement techniques. Prerequisite: MTGN451. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN552. INORGANIC MATRIX COMPOSITES. 3.0 Semester Hrs.
Introduction to the processing, structure, properties and applications of metal matrix and ceramic matrix composites. Importance of structure and properties of both the matrix and the reinforcement and the types of reinforcement utilized-particulate, short fiber, continuous fiber, and laminates. Emphasis on the development of mechanical properties through control of synthesis and processing parameters. Other physical properties such as electrical and thermal will also be examined. Prerequisite/Co-requisite*: MTGN352, MTGN445/MLGN505*. 3 hours lecture; 3 semester hours. (Summer of even years only.).

MTGN553. STRENGTHENING MECHANISMS. 3.0 Semester Hrs.
(II) Strain hardening in polycrystalline materials, dislocation inter actions, effect of grain boundaries on strength, solid solution hardening, martensitic transformations, precipitation hardening, point defects. Prerequisite: MTGN543 or concurrent enrollment. 3 hours lecture;3 semester hours. (Spring of even years only.).

MTGN554. OXIDATION OF METALS. 3.0 Semester Hrs.
(II) Kinetics of oxidation. The nature of the oxide film. Transport in oxides. Mechanisms of oxidation. The Oxidation protection of hightemperature metal systems. Prerequisite:none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN555. SOLID STATE THERMODYNAMICS. 3.0 Semester Hrs.
(I) Thermodynamics applied to solid state reactions, binary and ternary phase diagrams, point, line and planar defects, interfaces, and electrochemical concepts. Prerequisite: none. 3 hours lecture; 3 semester hours.

MTGN556. TRANSPORT IN SOLIDS. 3.0 Semester Hrs.
(I) Thermal and electrical conductivity. Solid state diffusion in metals and metal systems. Kinetics of metallurgical reactions in the solid state. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN557. SOLIDIFICATION. 3.0 Semester Hrs.
(I) Heat flow and fluid flow in solidification, thermodynamics of solidification, nucleation and interface kinetics, grain refining, crystal and grain growth, constitutional supercooling, eutectic growth, solidification of castings and ingots, segregation, and porosity. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN560. ANALYSIS OF METALLURGICAL FAILURES. 3.0 Semester Hrs.
(II) Applications of the principles of physical and mechanical metallurgy to the analysis of metallurgical failures. Nondestructive testing. Fractography. Case study analysis. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN561. PHYSICAL METALLURGY OF ALLOYS FOR AEROSPACE. 3.0 Semester Hrs.
(I) Review of current developments in aerospace materials with particular attention paid to titanium alloys, aluminum alloys, and metal-matrix composites. Emphasis is on phase equilibria, phase transformations, and microstructure-property relationships. Concepts of innovative processing and microstructural alloy design are included where appropriate. Prerequisite: none. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN564. ADVANCED FORGING AND FORMING. 3.0 Semester Hrs.
(II) Overview of plasticity. Examination and Analysis of working operations of forging, extrusion, rolling, wire drawing and sheet metal forming. Metallurgical structure evolution during working. Laboratory experiments involving metal forming processes. Prerequisites: MTGN445/MLGN505, 2 hours lecture; 3 hours lab, 3 semester hours.

MTGN565. MECHANICAL PROPERTIES OF CERAMICS AND COMPOSITES. 3.0 Semester Hrs.
(I) Mechanical properties of ceramics and ceramic-based composites; brittle fracture of solids; toughening mechanisms in composites; fatigue, high temperature mechanical behavior, including fracture, creep deformation. Prerequisites: MTGN445 or MLGN505. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN569,CHEN569,EGGN569,MEGN569,MLGN569,
(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

MTGN570. BIOCOMPATIBILITY OF MATERIALS. 3.0 Semester Hrs.
Equivalent with BELS570,
Introduction to the diversity of biomaterials and applications through examination of the physiologic environment in conjunction with compositional and structural requirements of tissues and organs. Appropriate domains and applications of metals, ceramics and polymers, including implants, sensors, drug delivery, laboratory automation, and tissue engineering are presented. Prerequisites: BIOL110 or equivalent. 3 hours lecture; 3 semester hours.

MTGN571. METALLURGICAL AND MATERIALS ENGINEERING LABORATORY. 1-3 Semester Hr.
Basic instruction in advanced equipment and techniques in the field of extraction, mechanical or physical metallurgy. Prerequisite: Selection. 3 to 9 hours lab ; 1 to 3 semester hours.

MTGN572. BIOMATERIALS. 3.0 Semester Hrs.
Equivalent with MLGN572,
(I) A broad overview on materials science and engineering principles for biomedical applications with three main topics: 1) The fundamental properties of biomaterials; 2) The fundamental concepts in biology; 3) The interactions between biological systems with exogenous materials. Examples including surface energy and surface modification; protein adsorption; cell adhesion, spreading and migration; biomaterials implantation and acute inflammation; blood-materials interactions and thrombosis; biofilm and biomaterials-related pathological reactions. Basic principles of bio-mimetic materials synthesis and assembly will also be introduced. 3 hours lecture; 3 semester hours.

MTGN580. ADVANCED WELDING METALLURGY. 3.0 Semester Hrs.
(II) Weldability of high strength steels, high alloys, and light metals; Welding defects; Phase transformations in weldments; Thermal experience in weldments; Pre- and Post-weld heat treatment; Heat affected zone formation, microstructure, and properties; Consumables development. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN581. WELDING HEAT SOURCES AND INTERACTIVE CONTROLS. 3.0 Semester Hrs.
(I) The science of welding heat sources including gas tungsten arc, gas metal arc, electron beam and laser. The interaction of the heat source with the workpiece will be explored and special emphasis will be given to using this knowledge for automatic control of the welding process. Prerequisite: Graduate Status. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN582. MECHANICAL PROPERTIES OF WELDED JOINTS. 3.0 Semester Hrs.
(II) Mechanical metallurgy of heterogeneous systems, shrinkage, distortion, cracking, residual stresses, mechanical testing of joints, size effects, joint design, transition temperature, fracture. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of odd years only.).

MTGN583. PRINCIPLES OF NON-DESTRUCTIVE TESTING AND EVALUATION. 3.0 Semester Hrs.
(I) Introduction to testing methods; basic physical principles of acoustics, radiography, and electromagnetism; statistical and risk analysis; fracture mechanics concepts; design decision making, limitations and applications of processes; fitness-for- service evaluations. Prerequisite: Graduate Status. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN584. NON-FUSION JOINING PROCESSES. 3.0 Semester Hrs.
(II) Joining processes for which the base materials are not melted. Brazing, soldering, diffusion bonding, explosive bonding, and adhesive bonding processes. Theoretical aspects of these processes, as well as the influence of process parameters. Special emphasis to the joining of dissimilar materials using these processes. Prerequisite: none. 3 hours lecture; 3 semester hours. (Spring of even years only.).

MTGN586. DESIGN OF WELDED STRUCTURES AND ASSEMBLIES. 3.0 Semester Hrs.
Introduction to the concepts and analytical practice of designing weldments. Designing for impact, fatigue, and torsional loading. Designing of weldments using overmatching and undermatching criteria. Analysis of combined stresses. Designing of compression members, column bases and splices. Designing of built-up columns, welded plate cylinders, beam-to-column connections, and trusses. Designing for tubular construction. Weld distortion and residual stresses. Joint design. Process consideration in weld design. Welding codes and specifications. Estimation of welding costs. Prerequisite/Co-requisite: MATH225 or equivalent, EGGN320 or equivalent, MTGN475. 3 hours lecture; 3 semester hours. (Summer of odd years only.).

MTGN587. PHYSICAL PHENOMENA OF WELDING AND JOINING PROCESSES. 3.0 Semester Hrs.
(I) Introduction to arc physics, fluid flow in the plasma, behavior of high pressure plasma, cathodic and anodic phenomena, energy generation and temperature distribution in the plasma, arc stability, metal transfer across arc, electron beam welding processes, keyhole phenomena. Ohmic welding processes, high frequency welding, weld pool phenomena. Development of relationships between physics concepts and the behavior of specific welding and joining processes. Prerequisite/Co-requisite: PHGN300, MATH225, MTGN475. 3 hours lecture; 3 semester hours. (Fall of even years only.).

MTGN591. PHYSICAL PHENOMENA OF COATING PROCESSES. 3.0 Semester Hrs.
(I) Introduction to plasma physics, behavior of low pressure plasma, cathodic and anodic phenomena, glow discharge phenomena, glow discharge sputtering, magnetron plasma deposition, ion beam deposition, cathodic arc evaporation, electron beam and laser coating processes. Development of relationships between physics concepts and the behavior of specific coating processes. Prerequisite/ Co-requisite: PHGN300, MATH225. 3 hours lecture; 3 semester hours. (Fall of odd years only.).

MTGN593. NUCLEAR MATERIALS SCIENCE AND ENGINEERING. 3.0 Semester Hrs.
(I) Introduction to the physical metallurgy of nuclear materials, including the nuclear, physical, thermal, and mechanical properties for nuclear materials, the physical and mechanical processing of nuclear alloys, the effect of nuclear and thermal environments on structural reactor materials and the selection of nuclear and reactor structural materials are described. Selected topics include ceramic science of ceramic nuclear material, ceramic processing of ceramic fuel, nuclear reaction with structural materials, radiation interactions with materials, the aging of nuclear materials, cladding, corrosion and the manufacturing of fuels elements. Relevant issues in the modern fuel cycle will also be introduced including nuclear safety, reactor decommissioning, and environmental impacts. Prerequisites: Graduate or Senior in good-standing. 3 hours lecture, 3 semester hours. (Fall of even years only.).

MTGN598. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MTGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MTGN605. ADVANCED TRANSMISSION ELECTRON MICROSCOPY. 2.0 Semester Hrs.
Introduction to transmission electron microscopy techniques and their application to materials characterization. Topics include electron optics, electron-specimen interactions, imaging, diffraction, contrast mechanisms, defect analyses, compositional measurements using energy dispersive x-ray spectroscopy and energy loss spectroscopy, scanning transmission electron microscopy, high angle annular dark field imaging, energy filtered TEM and high resolution phase contrast imaging. Prerequisite: MTGN 505. Co-requisite; MTGN 605L. 2 hours lecture, 2 semester hours.

MTGN605L. ADVANCED TRANSMISSION ELECTRON MICROSCOPY LABORATORY. 1.0 Semester Hr.
Specimen preparation techniques and their application to materials characterization. Topics include electron optics, electron-specimen interactions, imaging, diffraction, contrast mechanisms, defect analyses, compositional measurements using energy dispersive x-ray spectroscopy and energy loss spectroscopy, scanning transmission electron microscopy, high angle annular dark field imaging, energy filtered TEM and high resolution phase contrast imaging. Prerequisite: Concurrent enrollment in MTGN 605. 3 hours lab, 1 semester hour.

MTGN631. TRANSPORT PHENOMENA IN METALLURGICAL AND MATERIALS SYSTEMS. 3.0 Semester Hrs.
Physical principles of mass, momentum, and energy transport. Application to the analysis of extraction metallurgy and other physicochemical processes. Prerequisite: MATH225 and MTGN461 or equivalent. 3 hours lecture; 3 semester hours.

MTGN671. ADVANCED MATERIALS LABORATORY. 1-3 Semester Hr.
(I) Experimental and analytical research in the fields of production, mechanical, chemical, and/or physical metallurgy. Prerequisite: none. 1 to 3 semester hours; 3 semester hours.

MTGN672. ADVANCED MATERIALS LABORATORY. 1-3 Semester Hr.
(II) Continuation of MTGN671. 1 to 3 semester hours.

MTGN696. VAPOR DEPOSITION PROCESSES. 3.0 Semester Hrs.
(II) Introduction to the fundamental physics and chemistry underlying the control of deposition processes for thin films for a variety of applications? wear resistance, corrosion/oxidation resistance, decorative coatings, electronic and magnetic. Emphasis on the vapor deposition process varia - bles rather than the structure and properties of the deposited film. Prerequisites: MTGN351, MTGN461, or equivalent courses. 3 hours lecture; 3 semester hours. (Summer of odd years only.).

MTGN697. MICROSTRUCTURAL EVOLUTION OF COATINGS AND THIN FILMS. 3.0 Semester Hrs.
(I) Introduction to aqueous and non-aqueous chemistry for the preparation of an effective electrolyte; for interpretation of electrochemical principles associated with electrodeposition; surface science to describe surface structure and transport; interphasial structure including space charge and double layer concepts; nucleation concepts applied to electrodeposition; electrocrystallization including growth concepts; factors affecting morphology and kinetics; co-deposition of non-Brownian particles; pulse electrodeposition; electrodeposition parameters and control; physical metallurgy of electrodeposits; and, principles associated with vacuum evaporation and sputter deposition. Factors affecting microstructural evolution of vacuum and sputtered deposits; nucleation of vapor and sputtered deposits; modeling of matter-energy interactions during co-deposition; and, Thornton?s model for coating growth. Prerequisite/ co-requisite: MATH225, MTGN351, MTGN352. 3 hours lecture; 3 semester hours. (Summer of even years only.).

MTGN698. SPECIAL TOPICS IN METALLURGICAL AND MATERIALS ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MTGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MTGN700. GRADUATE RESEARCH CREDIT: MASTER OF ENGINEERING. 1-6 Semester Hr.
(I, II, S) Research credit hours required for completion of the degree Master of Engineering. Research under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. However, MTGN 705 credit hours may be transferred, in accordance with the requirements for this (M.E.) degree, by a Master of Science graduate-student who previously accumulated these credit-hours and subsequently opted to change their degree program to a Master of Engineering. Repeatable for credit. Variable: 1 to 6 semester hours.

MTGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

MILITARY SCIENCE (MSGN)

MSGN103. ADVENTURES IN LEADERSHIP I. 2.0 Semester Hrs.
(I) Introduces fundamentals of leadership and the United States Army. Examines its organization, customs, and history as well as its current relevance and purpose. Students also investigate basic leadership and management skills necessary to be successful in both military and civilian settings. Includes fundamentals of Army leadership doctrine, teambuilding concepts, time and stress management, an introduction to cartography and land navigation, marksmanship, briefing techniques, and some basic military tactics. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Fall).

MSGN104. ADVENTURES IN LEADERSHIP II. 2.0 Semester Hrs.
(II) Continues the investigation of leadership in small organizations. Covers selected topics such as basic troop leading procedures, military first aid and casualty evacuation concepts, creating ethical work climates, an introduction to Army organizations and installations, and a further examination of basic military tactics. Introduces students to effective military writing styles. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Spring).

MSGN198. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN203. METHODS OF LEADERSHIP. 2.0 Semester Hrs.
(I) Comprehensively reviews advanced leadership and management concepts including motivation, attitudes, communication skills, problem solving, human needs and behavior, and leadership self development. Students continue to refine effective written and oral communications skills and to explore topics such as the basic branches of the Army, and officer and NCO duties. Students conduct classroom and practical exercises in small unit light infantry tactics and are prepared to perform as midlevel leaders in the cadet organization. Lab fee: 1 hour lecture, 2 hours lab, 3 hours PT, and 80 hours field training; 2 semester hours. (Fall).

MSGN204. METHODS OF LEADERSHIP AND MANAGEMENT II. 2.0 Semester Hrs.
(II) Focuses on leadership and management functions in military and corporate environments. Studies various components of Army leadership doctrine to include the four elements of leadership, leadership principles, risk management and planning theory, the be-know-do framework, and the Army leadership evaluation program. Continue to refine communication skills. Lab fee. 1 hour lecture, 2 hours lab, 3 hours PT, and 80hours field training; 2 semester hours. (Spring).

MSGN298. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN301. MILITARY OPERATIONS AND TRAINING I. 3.0 Semester Hrs.
(I) Further explores the theory of managing and leading small military units with an emphasis on practical applications at the squad and platoon levels. Students examine various leadership styles and techniques as they relate to advanced small unit tactics. Familiarizes students with a variety of topics such as cartography, land navigation, field craft, and weapons systems. Involves multiple, evaluated leadership opportunities in field settings and hands-on experience with actual military equipment. Students are given maximum leadership opportunities in weekly labs. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN302. MILITARY OPERATIONS AND TRAINING II. 3.0 Semester Hrs.
(II) Studies theoretical and practical applications of small unit leadership principles. Focuses on managing personnel and resources, the military decision making process, the operations order, and oral communications. Exposes the student to tactical unit leadership in a variety of environments with a focus on preparation for the summer advance camp experience. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN303. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(I) Development of military leadership techniques to include preparation of operation plans, presentation of instruction, and supervision of underclass military cadets. Instruction in military drill, ceremonies, and customs and courtesies of the Army. Must be taken in conjunction with MSGN301. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Fall).

MSGN304. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(II) Continued development of military leadership techniques with the major emphasis on leading an Infantry Squad. Training is "handson." Practical exercises are used to increase understanding of the principles of leadership learned in MSGN302. Must be taken in conjunction with MSGN302. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, 80 hours field training; .5 semester hour. (Spring).

MSGN398. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN401. OFFICER LEADERSHIP AND DEVELOPMENT I. 3.0 Semester Hrs.
(I) Examines management and leadership concepts and techniques associated with planning and executing military training and operations at company and higher echelons. Includes analyses of professional ethics and values, effective training principles and procedures, subordinate counseling, and effective staff officer briefing techniques. Also investigates other subjects such as counter terrorism, modern peacekeeping missions, and the impact of the information revolution on the art of land warfare. Conducted both in and out of classroom setting and with multiple practical leadership opportunities to organize cadet training and activities. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Fall).

MSGN402. OFFICER LEADERSHIP AND DEVELOPMENT II. 3.0 Semester Hrs.
(II) Continues MSGN401 study of management and leadership concepts and techniques, providing practical leadership experiences in the classroom and during multiple cadet-run activities. Also examines varied topics such as theory and practice of the military justice system, law of war, military-media relations, support mechanisms for soldiers and their families, operational security considerations, and historical case studies in military leadership in the context of 21st century land warfare. Prerequisite: none. Lab Fee. 3 hours lecture; 3 semester hours. (Spring).

MSGN403. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(I) Continued development of leadership techniques by assignment in the command and staff positions in the Cadet Battalion. Cadets are expected to plan and execute much of the training associated with the day-to-day operations within the cadet battalion. Utilizing the troop leading and management principles learned in previous classes, cadets analyze the problems which the battalion faces, develop strategies, brief recommendations, and execute the approved plan. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Fall).

MSGN404. LEADERSHIP LABORATORY. 0.5 Semester Hrs.
(II) Continued leadership development by serving in the command and staff positions in the Cadet Battalion. Cadets take a large role in determining the goals and direction of the cadet organization, under supervision of the cadre. Cadets are required to plan and organize cadet outings and much of the training of underclassmen. Lab Fee. Prerequisite: none. Lab Fee. 2 hours lab, 3 hours PT, and 80 hours field training; .5 semester hour. (Spring).

MSGN498. SPECIAL TOPICS IN MILITARY SCIENCE. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MSGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MSGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MINING ENGINEERING (MNGN)

MNGN198. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN210. INTRODUCTORY MINING. 3.0 Semester Hrs.
INTRODUCTORY MINING (I, II) Survey of mining and mining economics. Topics include mining law, exploration and sampling, reserve estimation, project evaluation, basic unit operations including drilling, blasting, loading and hauling, support, shaft sinking and an introduction to surface and underground mining methods. Prerequisite: None. 3 hours lecture; 3 semester hours.

MNGN222. INTRODUCTION TO EXPLOSIVES ENGINEERING. 3.0 Semester Hrs.
(S) A basic introduction to explosives engineering and applied explosives science for students that recently completed their freshman or sophomore years at CSM. Topics covered will include safety and explosives regulations, chemistry of explosives, explosives physics, and detonation properties. The course features a significant hands-on practical laboratory learning component with several sessions held at the Explosives Research Laboratory (ERL) in Idaho Springs. Students completing this course will be well prepared for more advanced work in MNGN333 and MNGN444. Prerequisites: PHGN100, CHGN121, CHGN122, MATH111, and MATH112. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN298. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN300. SUMMER FIELD SESSION. 3.0 Semester Hrs.
(S) Classroom and field instructions in the theory and practice of surface and underground mine surveying. Introduction to the application of various computer-aided mine design software packages incorporated in upper division mining courses. Prerequisite: completion of sophomore year; Duration: first three weeks of summer term; 3 semester hours.

MNGN308. MINE SAFETY. 1.0 Semester Hr.
(I) Causes and prevention of accidents. Mine safety regulations. Mine rescue training. Safety management and organization. Prerequisite: MNGN210. 1 hour lecture; 1 semester hour. Taken as the first week of summer session.

MNGN309. MINING ENGINEERING LABORATORY. 2.0 Semester Hrs.
(I, II) Training in practical mine labor functions including: operation of jackleg drills, jumbo drills, muckers, and LHD machines. Training stresses safe operation of equipment and safe handling of explosives. Introduction to front-line management techniques. Prerequisite: MNGN210, MNGN308. 2 semester hours.

MNGN310. EARTH MATERIALS. 3.0 Semester Hrs.
(I) Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals and rocks. Structural features and processes are related to stress/strain theory and rock mechanics principles. Laboratories and field exercises emphasize the recognition, description and engineering evaluation of natural materials. Lectures and case study exercises present the knowledge of natural materials and processes necessary for mining engineering careers. Prerequisites: GEGN101. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN311. MINING GEOLOGY. 3.0 Semester Hrs.
(II) Introduction to Mining Geology, emphasizing the formation, distribution, engineering behavior, exploration for and geological aspects of development of ore materials. Laboratories emphasize the recognition, description and engineering evaluation of ores and their hosts. Lectures and case study exercises present the knowledge of ores and ore-forming processes necessary for mining engineering careers. Prerequisites: GEGN 101, (GEOL310 or MNGN310). 2 hours lecture; 3 hours lab: 3 semester hours.

MNGN312. SURFACE MINE DESIGN. 3.0 Semester Hrs.
(I) (WI) Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore estimates, unit operations, equipment selection, final pit determinations, short- and longrange planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN314. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.
(II) Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost estimates. Prerequisite: MNGN210 and MNGN300. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN316. COAL MINING METHODS. 3.0 Semester Hrs.
(II) (WI) Devoted to surface and underground coal mining methods and design. The surface mining portion emphasizes area-mining methods, including pertinent design-related regulations, and overburden removal systems. Pit layout, sequencing, overburden equipment selection and cost estimation are presented. The underground mining portion emphasizes general mine layout; detailed layout of continuous, conventional, longwall, and shortwall sections. General cost and manning requirements; and production analysis. Federal and state health and safety regulations are included in all aspects of mine layout. Pre - requisite: MNGN210. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN317. DYNAMICS FOR MINING ENGINEERS. 1.0 Semester Hr.
(II) For mining engineering majors only. Absolute and relative motions, kinetics, work-energy, impulse-momentum and angular impulse-momentum. Prerequisite: MATH213/223, CEEN241. 1 hour lecture; 1 semester hour.

MNGN321. INTRODUCTION TO ROCK MECHANICS. 3.0 Semester Hrs.
Physical properties of rock, and fundamentals of rock substance and rock mass response to applied loads. Principles of elastic analysis and stress-strain relationships. Elementary principles of the theoretical and applied design of underground openings and pit slopes. Emphasis on practical applied aspects. Prerequisite: CEEN241 or MNGN317. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN322. INTRODUCTION TO MINERAL PROCESSING AND LABORATORY. 3.0 Semester Hrs.
(I) Principles and practice of crushing, grinding, size classification; mineral concentration technologies including magnetic and electrostatic separation, gravity separation, and flotation. Sedimentation, thickening, filtration and product drying as well as tailings disposal technologies are included. The course is open to all CSM students. Prerequisite: PHGN200/ 210, MATH213/223. 2 hours lecture; 3 hours lab; 3 semester hours.

MNGN333. EXPLOSIVES ENGINEERING I. 3.0 Semester Hrs.
(I) This course gives students in engineering and applied sciences the opportunity to examine and develop a fundamental knowledge including terminology and understanding of explosives science and engineering concepts. Student learning will be demonstrated by assignments, quizzes, and exams. Learning assistance will come in the form of multidisciplinary lectures complemented by a few lectures from experts from government, industry and the explosives engineering community. Pre-requisites: None. 2 hours lecture; 3 hours lab. 3 semester hours.

MNGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

MNGN350. INTRODUCTION TO GEOTHERMAL ENERGY. 3.0 Semester Hrs.
Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include world wide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. Prerequisites: ENGY200. 3 hours lecture; 3 semester hours.

MNGN398. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI)) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN404. TUNNELING. 3.0 Semester Hrs.
(I) Modern tunneling techniques. Emphasis on evaluation of ground conditions, estimation of support requirements, methods of tunnel driving and boring, design systems and equipment, and safety. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN405. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.
(I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN406. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.
Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of in situ and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN407. ROCK FRAGMENTATION. 3.0 Semester Hrs.
(II) Theory and application of rock drilling, rock boring, explosives, blasting, and mechanical rock breakage. Design of blasting rounds, applications to surface and underground excavation. Prerequisite: CEEN241, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN408. UNDERGROUND DESIGN AND CONSTRUCTION. 2.0 Semester Hrs.
(I) Soil and rock engineering applied to underground civil works. Tunneling and the construction of underground openings for power facilities, water conveyance, transportation, and waste disposal; design, excavation and support of underground openings. Emphasis on consulting practice, case studies, geotechnical design, and construction methods. Prerequisite: CEEN312 OR MNGN321. 2 hours of lecture; 2 semester hours.

MNGN410. EXCAVATION PROJECT MANAGEMENT. 2.0 Semester Hrs.
(II) Successful implementation and management of surface and underground construction projects, preparation of contract documents, project bidding and estimating, contract awarding and notice to proceed, value engineering, risk management, construction management and dispute resolution, evaluation of differing site conditions claims. Prerequisite: MNGN 210, 2-hour lecture, 2 semester hours.

MNGN414. MINE PLANT DESIGN. 3.0 Semester Hrs.
(I) Analysis of mine plant elements with emphasis on design. Materials handling, dewatering, hoisting, belt conveyor and other material handling systems for underground mines. Prerequisite: MNGN312 and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hour.

MNGN418. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.
Equivalent with MNGN508,
Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. In-situ stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours.

MNGN421. DESIGN OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.
(II) Design of underground openings in competent and broken ground using rock mechanics principles. Rock bolting design and other ground support methods. Coal, evaporite, metallic and nonmetallic deposits included. Prerequisite: MNGN321, concurrent enrollment. 3 hours lecture; 3 semester hours.

MNGN422. FLOTATION. 2.0 Semester Hrs.
Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN423. FLOTATION LABORATORY. 1.0 Semester Hr.
(I) Experiments to accompany the lectures in MNGN422. Co-requisite: MNGN421. 3 hours lab; 1 semester hour.

MNGN424. MINE VENTILATION. 3.0 Semester Hrs.
(II) Fundamentals of mine ventilation, including control of gas, dust, temperature, and humidity; ventilation network analysis and design of systems. Prerequisites: PEGN251 or MEGN351, CHGN209 or MEGN361, and MNGN314. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN427. MINE VALUATION. 2.0 Semester Hrs.
(II) Course emphasis is on the business aspects of mining. Topics include time valuation of money and interest formulas, cash flow, investment criteria, tax considerations, risk and sensitivity analysis, escalation and inflation and cost of capital. Calculation procedures are illustrated by case studies. Computer programs are used. Prerequisite: Senior in Mining, graduate status. 2 hours lecture; 2 semester hours.

MNGN428. MINING ENGINEERING EVALUATION AND DESIGN REPORT I. 1.0 Semester Hr.
(I) (WI) Preparation of Phase I engineering report based on coordination of all previous work. Includes mineral deposit selection, geologic description, mining method selection, ore reserve determination, and permit process outline. Emphasis is on detailed mine design and cost analysis evaluation in preparation for MNGN429. Prerequisites: MNGN210, MNGN300, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, MNGN316, GEOL310, GEOL311. Co-requisites: MNGN438. 1 hour lecture; 1 semester hour.

MNGN429. MINING ENGINEERING EVALUATION AND DESIGN REPORT II. 2.0 Semester Hrs.
(II) (WI) Preparation of formal engineering report based on all course work in the mining option. Emphasis is on mine design, equipment selection, production scheduling, evaluation and cost analysis. Prerequisite: MNGN428, MNGN210, MNGN300, MNGN308, MNGN312, MNGN314, MNGN309, MNGN321, MNGN316, GEOL310, GEOL311, MNGN438, MNGN414. Co-requisites: MNGN322 or MNGN323, MNGN427, and MNGN433. 2 hours lecture; 2 semester hours.

MNGN431. MINING AND METALLURGICAL ENVIRONMENT. 3.0 Semester Hrs.
This course covers studies of the interface between mining and metallurgical process engineering and environmental engineering areas. Wastes, effluents and their point sources in mining and metallurgical processes such as mineral concentration, value extraction and process metallurgy are studied in context. Fundamentals of unit operations and unit processes with those applicable to waste and effluent control, disposal and materials recycling are covered. Engineering design and engineering cost components are also included for some examples chosen. The ratio of fundamentals applications coverage is about 1:1. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN433. MINE SYSTEMS ANALYSIS I. 3.0 Semester Hrs.
(II) Application of statistics, systems analysis, and operations research techniques to mineral industry problems. Laboratory work using computer techniques to improve efficiency of mining operations. Prerequisite: Senior or graduate status. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN434. PROCESS ANALYSIS. 1.0 Semester Hr.
Projects to accompany the lectures in MNGN422. Prerequisite: MNGN422. 3 hours lab; 1 semester hour.

MNGN436. UNDERGROUND COAL MINE DESIGN. 3.0 Semester Hrs.
(II) Design of an underground coal mine based on an actual coal reserve. This course shall utilize all previous course material in the actual design of an underground coal mine. Ventilation, materials handling, electrical transmission and distribution, fluid mechanics, equipment selection and application, mine plant design. Information from all basic mining survey courses will be used. Prerequisite: MNGN316, MNGN321, MNGN414, EGGN329 and MNGN381 or MNGN384. 3 hours lecture, 3 hours lab; 3 semester hours.

MNGN438. GEOSTATISTICS. 3.0 Semester Hrs.
(I) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MATH112. 2 hours of lecture and 3 hours of lab. 3 semester hours.

MNGN440. EQUIPMENT REPLACEMENT ANALYSIS. 2.0 Semester Hrs.
(I) Introduction to the fundamentals of classical equipment replacement theory. Emphasis on new, practical approaches to equipment replacement decision making. Topics include: operating and maintenance costs, obsolescence factors, technological changes, salvage, capital investments, minimal average annual costs, optimum economic life, infinite and finite planning horizons, replacement cycles, replacement vs. expansion, maximization of returns from equipment replacement expenditures. Prerequisite: MNGN427, senior or graduate status. 2 hours lecture; 2 semester hours.

MNGN444. EXPLOSIVES ENGINEERING II. 3.0 Semester Hrs.
(II) This course gives students in engineering and applied sciences the opportunity to acquire the fundamental concepts of explosives engineering and science applications as they apply to industry and real life examples. Students will expand upon their MNGN333 knowledge and develop a more advanced knowledge base including an understanding of the subject as it applies to their specific project interests. Assignments, quizzes, concept modeling and their project development and presentation will demonstrate student's progress. Prerequisite: MNGN333. 2 hours lecture, 3 hours lab, 3 semester hours.

MNGN445. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.
Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture; 3 semester hours.

MNGN452. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.
(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status; none. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN460. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregates industries. The course will cover resource definition, quarry planning and design, extraction, and processing of material for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth. Prerequisite: MNGN312, MNGN322, MNGN323. 3 hours lecture; 3 semester hours. Offered in spring.

MNGN470. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.
(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN482. MINE MANAGEMENT. 3.0 Semester Hrs.
(II) Basic principles of successful mine management including supervision skills, administrative policies, industrial and human relations, improvement engineering, risk management, conflict resolution and external affairs. Prerequisite: Senior or graduate status. 2 hours lecture and 1 hour case study presentation and discussion per week; 3 hours lecture; 3 semester hours.

MNGN490. ENERGY AND SOCIETY. 3.0 Semester Hrs.
Equivalent with ENGY490,LAIS490,
(II). A transdisciplinary capstone seminar that explores a spectrum of approaches to the understanding, planning, and implementation of energy production and use, including those typical of diverse private and public (national and international) corporations, organizations, states, and agencies. Aspects of global energy policy that may be considered include the historical, social, cultural, economic, ethical, political, and environmental aspects of energy together with comparative methodologies and assessments of diverse forms of energy development. Prerequisites: ENGY330/EBGN330 and one of either ENGY310, ENGY320, or ENGY340. 3 hours lecture/seminar; 3 semester hours.

MNGN498. SPECIAL TOPICS IN MINING ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MNGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) (WI) Individual research or special problem projects supervised by a faculty member. When a student and instructor agree on a subject matter, content, method of assessment, and credit hours, it must be approved by the Department Head. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MNGN501. REGULATORY MINING LAWS AND CONTRACTS. 3.0 Semester Hrs.
(I) Basic fundamentals of engineering law, regulations of federal and state laws pertaining to the mineral industry and environment control. Basic concepts of mining contracts. Offered in even numbered years. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN503. MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT. 3.0 Semester Hrs.
(I, II) The primary focus of this course is to provide students an understanding of the fundamental principles of sustainability and how they influence the technical components of a mine's life cycle, beginning during project feasibility and extending through operations to closure and site reclamation. Course discussions will address a wide range of traditional engineering topics that have specific relevance and impact to local and regional communities, such as mining methods and systems, mine plant design and layout, mine operations and supervision, resource utilization and cutoff grades, and labor. The course will emphasize the importance of integrating social, political, and economic considerations into technical decision-making and problem solving. 3 hours lecture; 3 semester hours.

MNGN504. UNDERGROUND CONSTRUCTION ENGINEERING IN HARD ROCK. 3.0 Semester Hrs.
(II) This course is developed to introduce students to the integrated science, engineering, design and management concepts of engineered underground construction. The course will cover advanced rock engineering in application to underground construction, geological interpretation and subsurface investigations, equipment options and system selection for projects with realistic constraints, underground excavation initial support and final shotcrete/lining design, and approaches to uncertainty evaluation and risk assessment for underground construction projects. Team design projects and presentations will be required. Prerequisites: CEEN513. Co-requisites: GEGN562. 3 hours lecture; 3 semester hours.

MNGN505. ROCK MECHANICS IN MINING. 3.0 Semester Hrs.
(I) The course deals with the rock mechanics aspect of design of mine layouts developed in both underground and surface. Underground mining sections include design of coal and hard rock pillars, mine layout design for tabular and massive ore bodies, assessment of caving characteristics or ore bodies, performance and application of backfill, and phenomenon of rock burst and its alleviation. Surface mining portion covers rock mass characterization, failure modes of slopes excavated in rock masses, probabilistic and deterministic approaches to design of slopes, and remedial measures for slope stability problems. Prerequisite: MN321 or equivalent. 3 hours lecture; 3 semester hours.

MNGN506. DESIGN AND SUPPORT OF UNDERGROUND EXCAVATIONS. 3.0 Semester Hrs.
Design of underground excavations and support. Analysis of stress and rock mass deformations around excavations using analytical and numerical methods. Collections, preparation, and evaluation of insitu and laboratory data for excavation design. Use of rock mass rating systems for site characterization and excavation design. Study of support types and selection of support for underground excavations. Use of numerical models for design of shafts, tunnels and large chambers. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN507. ADVANCED DRILLING AND BLASTING. 3.0 Semester Hrs.
(I) An advanced study of the theories of rock penetration including percussion, rotary, and rotary percussion drilling. Rock fragmentation including explosives and the theories of blasting rock. Application of theory to drilling and blasting practice at mines, pits, and quarries. Prerequisite: MNGN407. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN508. ADVANCED ROCK MECHANICS. 3.0 Semester Hrs.
Equivalent with MNGN418,
(I, II, S) Analytical and numerical modeling analysis of stresses and displacements induced around engineering excavations in rock. Insitu stress. Rock failure criteria. Complete load deformation behavior of rocks. Measurement and monitoring techniques in rock mechanics. Principles of design of excavation in rocks. Analytical, numerical modeling and empirical design methods. Probabilistic and deterministic approaches to rock engineering designs. Excavation design examples for shafts, tunnels, large chambers and mine pillars. Seismic loading of structures in rock. Phenomenon of rock burst and its alleviation. One additional design project will be assigned to graduate students. Prerequisites: MNGN321. 3 hours lecture; 3 semester hours.

MNGN509. CONSTRUCTION ENGINEERING AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with GOGN506,
(II) The course will provide content, methods and experience in construction planning and cost estimating, scheduling and equipment performance, contractual delivery systems and relationships, key contract clauses, risk registration and management, and project controls. Special attention will be paid to geotechnical uncertainty and risk, emerging technologies and industry trends, and to ethics and sustainability as applied to construction engineering and management practices. Co-requisites: GEGN562. 3 hours lecture; 3 semester hours.

MNGN510. FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT. 3.0 Semester Hrs.
Specifically designed for non-majors, the primary focus of this course is to provide students with a fundamental understanding of how mineral resources are found, developed, mined, and ultimately reclaimed. The course will present a wide range of traditional engineering and economic topics related to: exploration and resource characterization, project feasibility, mining methods and systems, mine plant design and layout, mine operations and scheduling, labor, and environmental and safety considerations. The course will emphasize the importance of integrating social (human), political, and environmental issues into technical decision-making and design. 3 hours lecture; 3 semester hours.

MNGN511. MINING INVESTIGATIONS. 2-4 Semester Hr.
(I, II) Investigational problems associated with any important aspect of mining. Choice of problem is arranged between student and instructor. Prerequisite: none. Lecture, consultation, lab, and assigned reading; 2 to 4 semester hours.

MNGN512. SURFACE MINE DESIGN. 3.0 Semester Hrs.
Analysis of elements of surface mine operation and design of surface mining system components with emphasis on minimization of adverse environmental impact and maximization of efficient use of mineral resources. Ore estimates, unit operations, equipment selection, final pit determinations, short- and long-range planning, road layouts, dump planning, and cost estimation. Prerequisite: MNGN210. 3 hours lecture; 3 semester hours.

MNGN514. MINING ROBOTICS. 3.0 Semester Hrs.
(I) Fundamentals of robotics as applied to the mining industry. The focus is on mobile robotic vehicles. Topics covered are mining applications, introduction and history of mobile robotics, sensors, including vision, problems of sensing variations in rock properties, problems of representing human knowledge in control systems, machine condition diagnostics, kinematics, and path finding. Prerequisite: CSCI404. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN515. MINE MECHANIZATION AND AUTOMATION. 3.0 Semester Hrs.
This course will provide an in-depth study of the current state of the art and future trends in mine mechanization and mine automation systems for both surface and underground mining, review the infrastructure required to support mine automation, and analyze the potential economic and health and safety benefits. Prerequisite: MNGN312, MNGN314, MNGN316. 2 hours lecture, 3 hours lab; 3 semester hours. Fall of odd years.

MNGN516. UNDERGROUND MINE DESIGN. 3.0 Semester Hrs.
Selection, design, and development of most suitable underground mining methods based upon the physical and the geological properties of mineral deposits (metallics and nonmetallics), conservation considerations, and associated environmental impacts. Reserve estimates, development and production planning, engineering drawings for development and extraction, underground haulage systems, and cost estimates. Prerequisite: MNGN210. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN517. ADVANCED UNDERGROUND MINING. 3.0 Semester Hrs.
(II) Review and evaluation of new developments in advanced underground mining systems to achieve improved productivity and reduced costs. The major topics covered include: mechanical excavation techniques for mine development and production, new haulage and vertical conveyance systems, advanced ground support and roof control methods, mine automation and monitoring, new mining systems and future trends in automated, high productivity mining schemes. Prerequisite: Underground Mine Design (e.g., MNGN314). 3 hours lecture; 3 semester hours.

MNGN518. ADVANCED BULK UNDERGROUND MINING TECHNIQUES. 3.0 Semester Hrs.
This course will provide advanced knowledge and understanding of the current state-of-the-art in design, development, and production in underground hard rock mining using bulk-mining methods. Design and layout of sublevel caving, block caving, open stoping and blasthole stoping systems. Equipment selection, production scheduling, ventilation design, and mining costs. Prerequisites: MNGN314, MNGN516. 2 hours lecture, 3 hours lab; 3 semester hours. Spring of odd years.

MNGN519. ADVANCED SURFACE COAL MINE DESIGN. 3.0 Semester Hrs.
(II) Review of current manual and computer methods of reserve estimation, mine design, equipment selection, and mine planning and scheduling. Course includes design of a surface coal mine for a given case study and comparison of manual and computer results. Prerequisite: MNGN312, 316, 427. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN520. ROCK MECHANICS IN UNDERGROUND COAL MINING. 3.0 Semester Hrs.
(I) Rock mechanics consideration in the design of room-and-pillar, longwall, and shortwall coal mining systems. Evaluation of bump and outburst conditions and remedial measures. Methane drainage systems. Surface subsidence evaluation. Prerequisite: MNGN321. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN522. FLOTATION. 3.0 Semester Hrs.
Science and engineering governing the practice of mineral concentration by flotation. Interfacial phenomena, flotation reagents, mineral-reagent interactions, and zeta-potential are covered. Flotation circuit design and evaluation as well as tailings handling are also covered. The course also includes laboratory demonstrations of some fundamental concepts. 3 hours lecture; 3 semester hours.

MNGN523. SELECTED TOPICS. 2-4 Semester Hr.
(I, II) Special topics in mining engineering, incorporating lectures, laboratory work or independent study, depending on needs. This course may be repeated for additional credit only if subject material is different. Prerequisite: none. 2 to 4 semester hours. Repeatable for credit under different titles.

MNGN524. ADVANCED MINE VENTILATION. 3.0 Semester Hrs.
(I) Advanced topics of mine ventilation including specific ventilation designs for various mining methods, ventilation numerical modeling, mine atmosphere management, mine air cooling, prevention and ventilation response to mine fires and explosions, mine dust control. Prerequisites: MNGN424 Mine Ventilation. Lecture and Lab Contact Hours: 3 hours lecture; 3 semester credit hours.

MNGN525. INTRODUCTION TO NUMERICAL TECHNIQUES IN ROCK MECHANICS. 3.0 Semester Hrs.
(I) Principles of stress and infinitesimal strain analysis are summarized, linear constitutive laws and energy methods are reviewed. Continuous and laminated models of stratified rock masses are introduced.
The general concepts of the boundary element and finite element methods are discussed. Emphasis is placed on the boundary element approach with displacement discontinui ties, because of its relevance to the modeling of the extraction of tabular mineral bodies and to the mobilization of faults, joints, etc. Several practical problems, selected from rock mechanics and subsidence engineering practices, are treated to demonstrate applications of the techniques. Prerequi site: MNGN321, EGGN320, or equivalent courses, MATH455. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN526. MODELING AND MEASURING IN GEOMECHANICS. 3.0 Semester Hrs.
(II) Introduction to instruments and instrumen tation systems used for making field measurements (stress, convergence, deformation, load, etc.) in geomechanics. Techniques for determining rock mass strength and deformability. Design of field measurement programs. Interpretation of field data. Development of predictive models using field data. Intro duction to various numerical techniques (boundary element, finite element, FLAC, etc.) for modeling the behavior of rock structures. Demonstration of concepts using various case studies. Prerequisite: Graduate standing. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in odd years.

MNGN527. THEORY OF PLATES AND SHELLS. 3.0 Semester Hrs.
Classical methods for the analysis of stresses in plate type structure are presented first. The stiffness matrices for plate element will be developed and used in the finite element method of analysis. Membrane and bending stresses in shells are derived. Application of the theory to tunnels, pipes, pressures vessels, and domes, etc., will be included. Prerequisites: EGGN320. 3 hours lecture; 3 credit hours.

MNGN528. MINING GEOLOGY. 3.0 Semester Hrs.
(I) Role of geology and the geologist in the development and production stages of a mining operation. Topics addressed: mining operation sequence, mine mapping, drilling, sampling, reserve estimation, economic evaluation, permitting, support functions. Field trips, mine mapping, data evaluation, exercises and term project. Prerequisite: GEGN401 or GEGN405. 2 hours lecture/seminar, 3 hours laboratory: 3 semester hours. Offered in even years.

MNGN529. URANIUM MINING. 2.0 Semester Hrs.
(I) Overview and introduction to the principles of uranium resource extraction and production. All aspects of the uranium fuel cycle are covered, including the geology of uranium, exploration for uranium deposits, mining, processing, environmental issues, and health and safety aspects. A lesser emphasis will be placed on nuclear fuel fabrication, nuclear power and waste disposal.

MNGN530. INTRODUCTION TO MICRO COMPUTERS IN MINING. 3.0 Semester Hrs.
(I) General overview of the use of PC based micro computers and software applications in the mining industry. Topics include the use of: database, CAD, spreadsheets, computer graphics, data acquisition, and remote communications as applied in the mining industry. Prerequisite: Any course in computer programming. 2 hours lecture, 3 hours lab; 3 semester hours.

MNGN536. OPERATIONS RESEARCH TECHNIQUES IN THE MINERAL INDUSTRY. 3.0 Semester Hrs.
Analysis of exploration, mining, and metallurgy systems using statistical analysis. Monte Carlo methods, simulation, linear programming, and computer methods. Prerequisite: MNGN433. 2 hours lecture, 3 hours lab; 3 semester hours. Offered in even years.

MNGN538. GEOSTATISTICAL ORE RESERVE ESTIMATION. 3.0 Semester Hrs.
(I) Introduction to the application and theory of geostatistics in the mining industry. Review of elementary statistics and traditional ore reserve calculation techniques. Presentation of fundamental geostatistical concepts, including: variogram, estimation variance, block variance, kriging, geostatistical simulation. Emphasis on the practical aspects of geostatistical modeling in mining. Prerequisite: MATH323 or equivalent course in statistics; graduate or senior status. 3 hours lecture; 3 semester hours.

MNGN539. ADVANCED MINING GEOSTATISTICS. 3.0 Semester Hrs.
(II) Advanced study of the theory and application of geostatistics in mining engineering. Presentation of state-of-the-art geostatistical concepts, including: robust estimation, nonlinear geostatistics, disjunctive kriging, geostatistical simulation, computational aspects. This course includes presentations by many guest lecturers from the mining industry. Emphasis on the development and application of advanced geostatistical techniques to difficult problems in the mining industry today. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN540. CLEAN COAL TECHNOLOGY. 3.0 Semester Hrs.
(I, II) Clean Energy - Gasification of Carbonaceous Materials - including coal, oil, gas, plastics, rubber, municipal waste and other substances. This course also covers the process of feedstock preparation, gasification, cleaning systems, and the output energy blocks along with an educational segment on CO products. These output energy blocks include feedstock to electrical power, feedstock to petroleum liquids, feedstock to pipeline quality gas. The course covers co- product development including urea, fertilizers, CO2 extraction/sequestration and chemical manufacturing.

MNGN545. ROCK SLOPE ENGINEERING. 3.0 Semester Hrs.
Introduction to the analysis and design of slopes excavated in rock. Rock mass classification and strength determinations, geological structural parameters, properties of fracture sets, data collection techniques, hydrological factors, methods of analysis of slope stability, wedge intersections, monitoring and maintenance of final pit slopes, classification of slides. Deterministic and probabilistic approaches in slope design. Remedial measures. Laboratory and field exercise in slope design. Collection of data and specimens in the field for deterring physical properties required for slope design. Application of numerical modeling and analytical techniques to slope stability determinations for hard rock and soft rock environments. Prerequisite: none. 3 hours lecture. 3 semester hours.

MNGN546. PM - MINE HEALTH AND SAFETY. 2.0 Semester Hrs.
(I, II, S) This course describes the principles of providing a safe and healthy work environment, focusing on the cultural and behavioral elements. Realigning long-learned human behaviors into a culture of safety and health consciousness is a significant management challenge, particularly in the developing world. Learning emphasis will be balanced among fundamentals, future trends, but risk will be a driver among discussion topics. Health and safety will be discussed in the context of the project cycle and also how the culture can transcend the workplace through mine employees to their families, neighbors and communities. 2 hours lecture; 2 semester hours.

MNGN547. PM - GEOLOGY AND MINING. 3.0 Semester Hrs.
(I, II, S) This course presents the relationship between geology and mining including the genesis of ore deposits, exploration, geochemistry, resource assessment, and mine planning. The relationship between the risks associated with reserve estimates and project finance are discussed. 3 hours lecture; 3 semester hours.

MNGN548. PM - INTEGRATED INFORMATION AND MINE SYSTEMS MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course presents facilities external to the mine that are necessary to support and maintain mining and waste handling operations, gather, store, and evaluate operating and maintenance databases. Focus will be on systems integration, emerging trends, automation, internet of things (IoT), managing bid data systems, cyber security, sensors, and data evaluation. 3 hours lecture; 3 semester hours.

MNGN549. MARINE MINING SYSTEMS. 3.0 Semester Hrs.
(I) Define interdisciplinary marine mining systems and operational requirements for the exploration survey, sea floor mining, hoisting, and transport. Describe and design components of deep-ocean, manganese-nodule mining systems and other marine mineral extraction methods. Analyze dynamics and remote control of the marine mining systems interactions and system components. Describe the current state-of-the-art technology, operational practice, trade-offs of the system design and risk. Prerequisite: EGGN351, EGGN320, GEOC408. 3 hours lecture; 3 semester hours. Offered alternate even years.

MNGN550. NEW TECHNIQUES IN MINING. 3.0 Semester Hrs.
(II) Review of various experimental mining procedures, including a critical evaluation of their potential applications. Mining methods covered include deep sea nodule mining, in situ gassification of coal, in situ retorting of oil shale, solution mining of soluble minerals, in situ leaching of metals, geothermal power generation, oil mining, nuclear fragmentation, slope caving, electro-thermal rock penetration and fragmentation. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN551. PM - MINE ACCOUNTING. 2.0 Semester Hrs.
(I, II, S) This course presents basic principles of accounting for mine engineers and managers. The preparation, content and analysis of financial statements and balance sheets from a managerial perspective are presented. Cost and accrual accounting for mine projects and operations is covered. Accounting standards in the U.S. and internationally are discussed. Mandatory financial reporting requirements for corporate entities are included in the course. 2 hours lecture; 2 semester hours.

MNGN552. SOLUTION MINING AND PROCESSING OF ORES. 3.0 Semester Hrs.
(II) Theory and application of advanced methods of extracting and processing of minerals, underground or in situ, to recover solutions and concentrates of value-materials, by minimization of the traditional surface processing and disposal of tailings to minimize environmental impacts. Prerequisite: Senior or graduate status. 3 hours lecture, 3 semester hours. Offered in spring.

MNGN553. PM - MINE DESIGN AND OPERATION PLANNING. 3.0 Semester Hrs.
(I, II, S) This course provides an overview of mine design and operating fundamentals with a focus on the emerging trends that will influence the mining industry. Topics provide an overarching significance to social, environmental, and sustainable factors during the design and operation of underground and surface mine planning. 3 hours lecture; 3 semester hours.

MNGN554. PM - MINE FINANCE. 2.0 Semester Hrs.
(I, II, S) This course applies the basic principles and concepts of financing in the mining industry. All methods of accessing capital for U.S. and international mining projects and operations will be presented. Asset and cash management throughout the mine life cycle will be discussed. Approaches to mergers and acquisitions, dividend policy and other financial decisions will be examined. Financial ratios, auditing and other financial controls will be taught. 2 hours lecture; 2 semester hours.

MNGN555. PM - MINE INVESTMENT EVALUATION. 3.0 Semester Hrs.
(I, II, S) This course provides an education in the evaluation of mine capital investments applying the principles of time value of money to after-tax cash flows. Implications of taxes, sustainability funding and debt financing are included. Methods of cost estimation for capital and operating budgets for feasibility studies are taught. The required content of feasibility studies at varying levels of detail is discussed. World standards for resource and reserve determination and public reporting requirements are presented. Methods for sensitivity analysis and real options analysis of mine capital investments are demonstrated. 3 hours lecture; 3 semester hours.

MNGN556. MINE WATER AND ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with CEEN556,
(I) This course will cover core aspects of mine water and mining geotechnics. The main topics to be covered relate to surface and groundwater flow along open pits and underground excavations, tailings and impoundments, mine spoils and waste rock, reclamation and closure. Course emphasizes leadership, teamwork, communication, and creative problem solving skills through the use of case examples, homework, and exams which emphasize typical water and geotechnical problems relevant to the mining industry. Prerequisite: CHGN121, CHGN122. 3 hours lecture, 3 semester hours.

MNGN557. PM - MINERAL ECONOMICS AND POLICY. 2.0 Semester Hrs.
(I, II, S) This course explores the determinants of demand for minerals and the factors that change that demand. The course covers sources of supply - primary, secondary and recycling for mineral commodities. The interaction of supply and demand and the impact on mineral markets is discussed. Public policy as it applies to taxation, economic development and sustainability is presented in both historical and future perspectives. 2 hours lecture; 2 semester hours.

MNGN558. PM - MINERAL PROCESSING. 3.0 Semester Hrs.
(I, II, S) This course presents the fundamentals for devising and specifying mineral processing systems to handle and beneficiate ores into salable concentrates. Ore sampling, testing programs, evaluations, and presentation methods are discussed. Emphasis is made to water and energy requirements, tailings management, and mill development from concept, construction, and operations. 3 hours lecture; 3 semester hours.

MNGN559. MECHANICS OF PARTICULATE MEDIA. 3.0 Semester Hrs.
(1) This course allows students to establish fundamental knowledge of quasi-static and dynamic particle behavior that is beneficial to interdisciplinary material handling processes in the chemical, civil, materials, metallurgy, geophysics, physics, and mining engineering. Issues of interst are the definition of particl size and size distribution, particle shape, nature of packing, quasi-static behavior under different external loading, particle collisions, kinetic theoretical modeling of particulate flows, molecular dynamic simulations, and a brief introduction of solid-fluid two-phase flows. Prerequisite: none. 3 hours lecture; 3 semester hours. Fall semesters, every other year.

MNGN560. INDUSTRIAL MINERALS PRODUCTION. 3.0 Semester Hrs.
(II) This course describes the engineering principles and practices associated with quarry mining operations related to the cement and aggregate industries. The course will cover resource definition, quarry planning and design, extraction, and processing of minerals for cement and aggregate production. Permitting issues and reclamation, particle sizing and environmental practices, will be studied in depth.

MNGN561. PM - PROJECT MANAGEMENT. 3.0 Semester Hrs.
(I, II, S) This course covers project management from major mine construction projects to business improvement projects. Project organization, delivery methods, controls and other aspects of managing projects big and small will be included. Methods for creating improvement results, managing risk, decision-making under conditions of uncertainty and optimizing mining processes will be discussed extensively. Strategies for resolving conflicts that occur in business will be taught. 3 hours lecture; 3 semester hours.

MNGN562. PM - MINING ENVIRONMENTAL AND SOCIAL RESPONSIBILITY. 2.0 Semester Hrs.
(I, II, S) This course describes the fundamentals of mine environmental and social evaluations and controls, including mine permitting, compliance, impact assessment and analysis and the development of effective environmental and social management systems. The course will stress the execution of these elements in a culturally appropriate manner and the risk to project continuity and corporate reputation if these fundamentals are mishandled. Sustainability and project life cycle aspects will be integrated throughout the course. 2 hours lecture; 2 semester hours.

MNGN563. PM - WATER WASTE AND MINE CLOSURE. 3.0 Semester Hrs.
(I, II, S) The course addresses the fundamentals and future trends in water and waste management and the design and implementation of mine closure techniques. Emphasis will be placed on the environmental, social, and cost control risks. Topics covered include: 1) water supply, disposal and treatment, 2) site-wide water management, 3) mine waste rock management, 4) process waste and tailings management, 5) solid, hazardous and medical waste disposal, 6) closure design (conceptual to construction-ready), and 7) post-closure elements. The importance of effective water and waste management practices, as well as integrating closure planning techniques into engineering designs, will be stressed throughout the project life cycle. 3 hours lecture; 3 semester hours.

MNGN565. MINE RISK MANAGEMENT. 3.0 Semester Hrs.
(II) Fundamentals of identifying, analyzing, assessing and treating risks associated with the feasibility, development and operation of mines. Methodologies for identifying, assessing and treating risks will be presented and practiced in case studies and exercises. Concepts and principles for analyzing risks will be demonstrated and practiced utilizing deterministic and stochastic models, deductive models, decision trees and other applicable principles. 3 hours lecture; 3 semester hours.

MNGN570. SAFETY AND HEALTH MANAGEMENT IN THE MINING INDUSTRY. 3.0 Semester Hrs.
(I) Fundamentals of managing occupational safety and health at a mining operation. Includes tracking of accident and injury statistics, risk management, developing a safety and health management plan, meeting MSHA regulatory requirements, training, safety audits and accident investigations. 3 hours lecture; 3 semester hours.

MNGN575. HEAT MINING. 3.0 Semester Hrs.
(I) Heat Mining focuses on identifying available sub-surface heat sources. Heat trapped in crystalline rock deep underground is available by engineering an artificial geothermal system. Hot geothermal fluid, heat generated by underground coal fire and hot water trapped in abandoned underground mine are some of other examples. We will discuss how to find them, how to estimate them, and how to extract and convert them to a usable energy form. The concept of sustainable resource development will be taught as the foundation of heat mining. Prerequisites: None. 3 hours lecture; 3 semester hours.

MNGN585. MINING ECONOMICS. 3.0 Semester Hrs.
(I) Advanced study in mine valuation with emphasis on revenue and cost aspects. Topics include price and contract consideration in coal, metal and other commodities; mine capital and operating cost estimation and indexing; and other topics of current interest. Prerequisite: MNGN427 or EBGN504 or equivalent. 3 hours lecture; 3 semester hours. Offered in even years.

MNGN590. MECHANICAL EXCAVATION IN MINING. 3.0 Semester Hrs.
(II) This course provides a comprehensive review of the existing and emerging mechanical excavation technologies for mine development and production in surface and underground mining. The major topics covered in the course include: history and development of mechanical excavators, theory and principles of mechanical rock fragmentation, design and performance of rock cutting tools, design and operational characteristics of mechanical excavators (e.g. continuous miners, roadheaders, tunnel boring machines, raise drills, shaft borers, impact miners, slotters), applications to mine development and production, performance prediction and geotechnical investigations, costs versus conventional methods, new mine designs for applying mechanical excavators, case histories, future trends and anticipated developments and novel rock fragmentation methods including water jets, lasers, microwaves, electron beams, penetrators, electrical discharge and sonic rock breakers. Prerequisite: Senior or graduate status. 3 hours lecture; 3 semester hours. Offered in odd years.

MNGN598. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN625. GRADUATE MINING SEMINAR. 1.0 Semester Hr.
(I, II) Discussions presented by graduate students, staff, and visiting lecturers on research and development topics of general interest. Required of all graduate students in mining engineering every semester during residence. 1 semester hour upon completion of thesis or residence.

MNGN698. SPECIAL TOPICS IN MINING ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MNGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MNGN700. GRADUATE ENGINEERING REPORTMASTER OF ENGINEERING. 1-6 Semester Hr.
(I, II) Laboratory, field, and library work for the Master of Engineering report under supervision of the student?s advisory committee. Required of candidates for the degree of Master of Engineering. Variable 1 to 6 hours. Repeatable for credit to a maximum of 6 hours.

MNGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

MUSIC (LIMU)

LIMU101. CONCERT/MARCH BAND-FRESHMAN. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU102. SCHOOL OF MINES SYMPHONY ORCHESTRA - FRESHMAN. 1.0 Semester Hr.
(I, II, S) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.

LIMU111. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU112. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU121. GUITAR ENSEMBLE. 1.0 Semester Hr.
(I, II, S) Students will learn the basics of classical guitar playing in a non-threatening environment. Utilizing beginning to intermediate classical guitar tunes, students will advance the fundamental guitar technique as well as the music reading skill on classical guitar. Reading skill is the foundation of students? future engagement with all forms of music, therefore considerable amount of class resources will be devoted to this particular discipline. Participation in the departmental concert at the end of the semester is mandatory. Offered every other year. 3 hours lab; 1 semester hour.

LIMU189. INDIVIDUAL INSTRUMENTAL OR VOCAL MUSIC INSTRUCTION. 1.0 Semester Hr.
(I, II) The course affords the student an opportunity to study privately with CSM music faculty on a wide range of instruments including guitar, piano, bass guitar, voice, saxophone, flute, drums and world instruments. Students will be required to practice regularly and demonstrate proficiency on their instrument/voice. Topics of this class will include performance etiquette, musicianship, musical styles, stylistic vocabulary, foreign language and basic music theory. 1 credit hour.

LIMU198. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU201. CONCERT/MARCH BAND-SOPHOMORE. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU202. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - SOPHOMORE. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.

LIMU211. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU212. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU301. CONCERT/MARCH BAND-JUNIOR. 1.0 Semester Hr.
Study, rehearsal, and performance of concert, marching and stage repertory. Emphasis on fundamentals of rhythm, intonation, embouchure, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU302. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - JUNIOR. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.

LIMU311. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU312. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

LIMU401. CONCERT/MARCH BAND-JUNIOR. 1.0 Semester Hr.
(I) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. 3 hours lab; 1 semester hour.

LIMU402. COLORADO SCHOOL OF MINES SYMPHONY ORCHESTRA - SENIOR. 1.0 Semester Hr.
(II) The Colorado School of Mines Symphony Orchestra is a full orchestra including strings, woodwinds, brass, and percussion. The orchestra studies a wide range of repertoire including standard orchestral works in addition to popular selections, film soundtracks, and chamber ensemble pieces. Performances include formal concerts, silent film soundtrack productions, and chamber music recitals; while performance frequency varies by semester, there are typically one to two large-ensemble performances per semester and one to three chamber performances per semester. Grading is based on individual participation and preparation. Offered every other year. 3 hours lab; 1 semester hour.

LIMU411. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU412. CHORUS. 1.0 Semester Hr.
Study, rehearsal, and performance of choral music of the classical, romantic, and modern periods with special emphasis on principles of diction, rhythm, intonation, phrasing, and ensemble. 2 hours rehearsal; 1 semester hour. Not repeatable using same course number. See rules limiting the number of hours applicable to a degree above.

LIMU421. JAZZ ENSEMBLE. 1.0 Semester Hr.
FALL The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance (s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU422. JAZZ ENSEMBLE/PEP BAND - SPRING. 1.0 Semester Hr.
SPRING The Jazz Ensemble provides an opportunity for students to participate in a musical ensemble in the jazz big band format. Jazz music is a unique American art form. The big band jazz format is an exciting way for students to experience the power, grace and beauty of this art form and music in general. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU423. JAZZ LAB. 1.0 Semester Hr.
The Jazz Lab provides an opportunity for students to participate in a musical ensemble in the jazz combo format. Jazz music is a unique American art form. The jazz combo format is an exciting way for students to experience the joy and sense of achievement of performing this great American music form. The class will consist of regular weekly rehearsals and one or more concert performance(s). 1 semester hour. Repeatable for credit. See rules limiting the number of hours applicable to a degree above.

LIMU450. MUSIC TECHNOLOGY CAPSTONE COURSE. 3.0 Semester Hrs.
Project-based course designed to develop practical technological and communication skills for direct application to the music recording. Prerequisite: LIMU340 and LIMU350. 3 hours seminar; 3 semester hours.

LIMU498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

LIMU499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

NUCLEAR ENGINEERING (NUGN)

NUGN505. NUCLEAR SCIENCE AND ENGINEERING SEMINAR. 1.0 Semester Hr.
(I, II) The Nuclear Science and Engineering Seminar provides a forum for Nuclear Engineering graduate students to present their research projects, participate in seminars given by Nuclear Science and Engineering professionals, and develop an enhanced understanding of the breadth of the nuclear engineering discipline. Prerequsite: gradaute standing. 1 hour seminar; 1 semester hour. Repeatable; maximum 2 hours granted towards M.S./M.E. Degree Requirements and 4 hours maximum granted towards Ph.D. Requirements.

NUGN506. NUCLEAR FUEL CYCLE. 3.0 Semester Hrs.
(I) An introduction to nuclear energy emphasizing the science, engineering, and policies underlying the systems and processes involved in energy production by nuclear fission. Students will acquire a broad understanding of nuclear energy systems framed in the context of the fuel used to power nuclear reactors. 3 hours lecture; 3 semester hours.

NUGN510. INTRODUCTION TO NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
(II) Bridges the gap between courses in fundamental nuclear physics and the neutronic design and analysis of nuclear reactors. Review of neutron energetics and reactions; nuclear cross sections; neutron induced fission; neutron life cycle, multiplication, and criticality; nuclear reactor kinetics and control; the diffusion approximation for neutron transport; simple reactor geometries and compositions; modeling and simulation of reactors. Prerequisite: PHGN422. 3 hours lecture; 3 semester hours.

NUGN520. INTRODUCTION TO NUCLEAR REACTOR THERMAL-HYDRAULICS. 3.0 Semester Hrs.
(II) Bridges the gap between fundamental courses in thermodynamics, fluid flow, and heat transer and the thermal-hydraulic design and analysis of nuclear reactors. Provides a comprehensive introduction to the thermal-hydraulics of each of the major classes of nuclear reactors. Introduces the major thermal-hydraulic computational tools, passively safe reactor design, thermal-hydraulic transient analysis, and severe nuclear reactor accident analysis.

NUGN535. INTRODUCTION TO HEALTH PHYSICS. 3.0 Semester Hrs.
(I) Health physics evaluates effects of ionizing radiation on biological systems for the safe use of radiation and control of potential health hazards. The core concept is dosimetry, which relates the radiation absorbed externally and internally to a quantitative estimate of health effects. Other areas in health physics such as protection standards, regulations, and radiation diagnosis and therapy are all constructed on dosimetric methods.

NUGN580. NUCLEAR REACTOR LABORATORY. 3.0 Semester Hrs.
(I) Provides hands-on experience with a number of nuclear reactor operations topics. Reactor power calibration; gamma spectroscopy; neutron activation analysis; reactor flux and power profiles; reactor criticality; control rod worth; xenon transients and burnout; reactor pulsing. Taught at the USGS TRIGA reactor. Prerequisite: NUGN510. 3 hours laboratory; 3 semester hours.

NUGN585. NUCLEAR REACTOR DESIGN I. 2.0 Semester Hrs.
(I) Provides a basic understanding of the nuclear reactor design process, including: key features of nuclear reactors; nuclear reactor design principles; identification of design drivers; neutronic and thermal-hydraulic design of nuclear reactors; reactor safety considerations; relevant nuclear engineering computer codes. Prerequisite: NUGN510. 2 hours lecture; 2 semester hours.

NUGN586. NUCLEAR REACTOR DESIGN II. 2.0 Semester Hrs.
(II) Builds on the design experience obtained in NUGN586 to provide an in-depth understanding of the nuclear reactor design process. Prerequisites: NUGN585 (taken in the same academic year). 2 hours lecture; 2 semester hours.

NUGN590. COMPUTATIONAL REACTOR PHYSICS. 3.0 Semester Hrs.
(I) This course will provide an introduction to computational nuclear reactor physics. Students will understand the physics driving neutron cross sections and how they determined, and how neutron transport calculations are completed using Monte Carlo and finite difference methods. Students will learn how to write modular code using professional software engineering practices, and will have an introduction to the Serpent and MCNP family of transport codes. 3 hours lecture; 3 semester hours.

NUGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN599. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

NUGN699. INDEPENDENT STUDY IN NUCLEAR ENGINEERING. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

NUGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

OCEANOGRAPHY (GEOC)

GEOC407. ATMOSPHERE, WEATHER AND CLIMATE. 3.0 Semester Hrs.
(II) An introduction to the Earth?s atmosphere and its role in weather patterns and long term climate. Provides basic understanding of origin and evolution of the atmosphere, Earth?s heat budget, global atmospheric circulation and modern climatic zones. Long- and short-term climate change including paleoclimatology, the causes of glacial periods and global warming, and the depletion of the ozone layer. Causes and effects of volcanic eruptions on climate, El Nino, acid rain, severe thunderstorms, tornadoes, hurricanes, and avalanches are also discussed. Microclimates and weather patterns common in Colorado. Prerequisite: Completion of CSM freshman technical core, or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

GEOC408. INTRODUCTION TO OCEANOGRAPHY. 3.0 Semester Hrs.
(II) An introduction to the scientific study of the oceans, including chemistry, physics, geology, biology, geophysics, and mineral resources of the marine environment. Lectures from pertinent disciplines are included. Recommended background: basic college courses in chemistry, geology, mathematics, and physics. 3 hours lecture; 3 semester hours. Offered alternate years.

PETROLEUM ENGINEERING (PEGN)

PEGN102. INTRODUCTION TO PETROLEUM INDUSTRY. 3.0 Semester Hrs.
(II) A survey of the elements comprising the petroleum industry-exploration, development, processing, transportation, distribution, engineering ethics and professionalism. This elective course is recommended for all PE majors, minors, and other interested students. 3 hours lecture; 3 semester hours.

PEGN198. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN251. FLUID MECHANICS. 3.0 Semester Hrs.
(I, II) Fundamental course in engineering fluid flow introducing flow in pipelines, surface facilities and oil and gas wells. Theory and application of incompressible and compressible flow, fluid statics, dimensional analysis, laminar and turbulent flow, Newtonian and non-Newtonian fluids, and two-phase flow. Lecture format with demonstrations and practical problem solving, coordinated with PEGN308. May not also receive credit for MEGN351 or CEEN310. Co-requisites: CEEN241. 3 hours lecture; 3 semester hours.

PEGN298. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN305. COMPUTATIONAL METHODS IN PETROLEUM ENGINEERING. 2.0 Semester Hrs.
(I) This course is an introduction to computers and computer programming applied to petroleum engineering. Emphasis will be on learning Visual Basic programming techniques to solve engineering problems. A toolbox of fluid property and numerical techniques will be developed. Prerequisite: MATH213. 2 hours lecture; 2 semester hours.

PEGN308. RESERVOIR ROCK PROPERTIES. 3.0 Semester Hrs.
(I, II) (WI) Introduction to basic reservoir rock properties and their measurements. Topics covered include: porosity, saturations, volumetric equations, land descriptions, trapping mechanism, pressure and temperature gradient, abnormally pressured reservoirs. Darcy's law for linear horizontal and tilted flow, radial flow for single phase liquids and gases, multiphase flow (relative permeability). Capillary pressure and formation compressibility are also discussed. Co-requisites: CEEN241, PEGN251. 2 hours lecture; 3 hours lab; 3 semester hours.

PEGN311. DRILLING ENGINEERING. 4.0 Semester Hrs.
(I) Study of drilling operations, fluid design, hydraulics, drilling contracts, rig selection, rotary system, well control, bit selection, drill string design, directional drilling, and casing seat selection. Prerequisites: PEGN251 (grade of C or higher), PEGN315, CEEN241. Co-requisites: PEGN305. 3 hours lecture; 3 hours lab; 4 semester hours.

PEGN312. PROPERTIES OF PETROLEUM ENGINEERING FLUIDS. 3.0 Semester Hrs.
(I) (WI) Properties of fluids encountered in petroleum engineering including reservoir, drilling, and completion fluids, and oilfield waters. Phase behavior, density, viscosity, interfacial tension, and composition of oil, gas, and brine systems. Interpreting lab data for engineering applications. Flash calculations with k-values and equation of state. Introduction to fluid properties software. Laboratory experimentation of fluid properties. Prerequisites: PEGN308 (C or better), CHGN209 (C or better). 2 hours lecture; 3 hours lab; 3 semester hours.

PEGN315. SUMMER FIELD SESSION I. 1.0 Semester Hr.
(S) This 8 day course taken after the completion of the sophomore year is designed to introduce the student to oil and gas field and other engineering operations. Engineering design problems are integrated throughout the 8 day session. On-site visits to various oil field operations in the past included the Rocky Mountain region, the U.S. Gulf Coast, California, Alaska, Canada and Europe. Topics covered include drilling, completions, stimulations, surface facilities, production, artificial lift, reservoir, geology and geophysics. Also included are environmental and safety issues as related to the petroleum industry. Prerequisite: PEGN308 (grade C or better). 3 hours lab; 1 semester hour.

PEGN316. SUMMER FIELD SESSION II. 2.0 Semester Hrs.
(S) This two week course is taken after the completion of the junior year. Emphasis is placed on the multidisciplinary nature of reservoir management. Field trips in the area provide the opportunity to study eolian, fluvial, lacustrine, near shore, and marine depositional systems. These field trips provide the setting for understanding the complexity of each system in the context of reservoir development and management. Petroleum systems including the source, maturity, and trapping of hydrocarbons are studied in the context of petroleum exploration and development. Geologic methods incorporating both surface and subsurface data are used extensively. Prerequisites: PEGN315, PEGN419, GEOL308, and GEOL315. 6 hours lab; 2 semester hours.

PEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions.

PEGN350. SUSTAINABLE ENERGY SYSTEMS. 3.0 Semester Hrs.
(I or II) A sustainable energy system is a system that lets us meet present energy needs while preserving the ability of future generations to meet their needs. Sustainable Energy Systems introduces undergraduate students to sustainable energy systems that will be available in the 21st century. The course focuses on sustainable energy sources, especially renewable energy sources and nuclear energy (e.g., fusion). Students are introduced to the existing energy infrastructure, become familiar with finite energy sources, and learn from a study of energy supply and demand that sustainable energy systems are needed. The ability to improve energy use efficiency and the impact of energy sources on the environment are discussed. Examples of sustainable energy systems and their applicability to different energy sectors are presented. The course is recommended for students who plan to enter the energy industry or students who would like an introduction to sustainable energy systems. Prerequisites: EDNS151. 3 hours lecture; 3 semester hours.

PEGN361. COMPLETION ENGINEERING. 3.0 Semester Hrs.
(II) (WI) This class is a continuation from drilling in PEGN311 into completion operations. Topics include casing design, cement planning, completion techniques and equipment, tubing design, wellhead selection, and sand control, and perforation procedures. Prerequisites: PEGN311, and CEEN311 or MEGN312. 3 hours lecture; 3 semester hours.

PEGN398. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN411. MECHANICS OF PETROLEUM PRODUCTION. 3.0 Semester Hrs.
(II) Nodal analysis for pipe and formation deliverability including single and multiphase flow. Natural flow and design of artificial lift methods including gas lift, sucker rod pumps, electrical submersible pumps, and hydraulic pumps. Prerequisites: PEGN251, PEGN308 (grade of C or better), PEGN311, and PEGN312. 3 hours lecture; 3 semester hours.

PEGN414. WELL TESTING AND ANALYSIS. 3.0 Semester Hrs.
(I) Solution to the diffusivity equation. Transient well testing: build-up, drawdown, multi-rate test analysis for oil and gas. Flow tests and well deliverabilities. Type curve analysis. Super position, active and interference tests. Well test design. Prerequisites: MATH225 and PEGN419. 3 hours lecture; 3 semester hours.

PEGN419. WELL LOG ANALYSIS AND FORMATION EVALUATION. 3.0 Semester Hrs.
Equivalent with GPGN419,
(II) An introduction to well logging methods, including the relationship between measured properties and reservoir properties. Analysis of log suites for reservoir size and content. Graphical and analytical methods will be developed to allow the student to better visualize the reservoir, its contents, and its potential for production. Use of the computer as a tool to handle data, create graphs and log traces, and make computations of reservoir parameters is required. Prerequisites: GEOL315, PHGN 200 (grade of C or better). 3 hours lecture; 3 semester hours.

PEGN422. ECONOMICS AND EVALUATION OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.
(I) Project economics for oil and gas projects under conditions of certainty and uncertainty. Topics include time value of money concepts, discount rate assumptions, measures of project profitability, costs, taxes, expected value concept, decision trees, gambler?s ruin, and Monte Carlo simulation techniques. 3 hours lecture; 3 semester hours.

PEGN423. PETROLEUM RESERVOIR ENGINEERING I. 3.0 Semester Hrs.
(II) Data requirements for reservoir engineering studies. Material balance calculations for normal gas, retrograde gas condensate, solution-gas and gas-cap reservoirs with or without water drive. Primary reservoir performance. Forecasting future recoveries by incremental material balance. Prerequisites: PEGN419 and (MATH225 or MATH235 or MATH222 only for non PE majors). 3 hours lecture; 3 semester hours.

PEGN424. PETROLEUM RESERVOIR ENGINEERING II. 3.0 Semester Hrs.
(II) Reservoir engineering aspects of supplemental recovery processes. Introduction to liquid-liquid displacement processes, gas-liquid displacement processes, and thermal recovery processes. Introduction to numerical reservoir simula tion, history matching and forecasting. Prerequisite: PEGN423 and PEGN438. 3 hours lecture; 3 semester hours.

PEGN426. FORMATION DAMAGE AND STIMULATION. 3.0 Semester Hrs.
(II) Completion parameters; design for well conditions. Skin damage associated with completions and well productivity. Fluid types and properties;characterizations of compatibilities. Stimulation techniques; acidizing and fracturing. Selection of proppants and fluids; types, placement and compatibilities. Estimation of rates, volumes and fracture dimensions. Reservoir considerations in fracture propagation and design. Prerequisite: PEGN361 and PEGN411. 3 hours lecture; 3 semester hours.

PEGN428. ADVANCED DRILLING ENGINEERING. 3.0 Semester Hrs.
(II) Rotary drilling systems with emphasis on design of drilling programs, directional and horizontal well planning. This elective course is recommended for petroleum engineering majors interested in drilling. Prerequisite: PEGN311, PEGN361. 3 hours lecture; 3 semester hours.

PEGN430. ENVIRONMENTAL LAW AND SUSTAINABILITY. 3.0 Semester Hrs.
(II) (WI) In this course students will be introduced to the fundamental legal principles that are relevant to sustainable engineering project development. General principles of United States (U.S.) environmental regulation pertaining to air quality, water quality, waste management, hazardous substances remediation, regulation of chemical manufacture and distribution, natural resources, and energy will be discussed in parallel with international laws pertaining to environmental protection and human rights. In the context of engineering project design, students will explore legal, societal, and ethical risks, and risk mitigation methodologies. 3 hours lecture; 3 semester hours.

PEGN438. PETROLEUM DATA ANALYTICS. 3.0 Semester Hrs.
(II) Introduction to elementary probability theory and its applications in engineering and sciences; discrete and continuous probability distributions; parameter estimation; hypothesis testing; linear regression; spatial correlations and geostatistics with emphasis on applications in earth sciences and engineering. Prerequisites: MATH112. 2 hours lecture; 3 hours lab; 3 semester hours.

PEGN439. MULTIDISCIPLINARY PETROLEUM DESIGN. 3.0 Semester Hrs.
Equivalent with GEGN439,GPGN439,
(II) (WI) This is a multi-disciplinary design course that integrates fundamentals and design concepts in geology, geophysics, and petroleum engineering. Students work in integrated teams consisting of students from each of the disciplines. Multiple open-ended design problems in oil and gas exploration and field development, including the development of a prospect in an exploration play and a detailed engineering field study are assigned. Several detailed written and oral presentations are made throughout the semester. Project economics including risk analysis are an integral part of the course. Prerequisites: GE Majors: GEOL309, GEOL314, GEGN438, and EDNS264; GP Majors: GPGN304, GPGN305, and GPGN268; PE Majors: GEOL308, PEGN316. Co-requisites: PEGN426. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN440. PETROLEUM DATA ANALYSIS. 3.0 Semester Hrs.
(II) Capstone course for Petroleum Data Analytics minor. The course starts with an introduction to data analysis and visualization packages. The course then has three projects to include drilling, production, and reservoir data analysis along with data visualization techniques. The student will be required to prepare both oral and written and oral project updates and final results. Prerequisites: EBGN325, CSCI303, and PEGN438. 3 hours lecture; 3 semester hours.

PEGN450. ENERGY ENGINEERING. 3.0 Semester Hrs.
(I or II) Energy Engineering is an overview of energy sources that will be available for use in the 21st century. After discussing the history of energy and its contribution to society, we survey the science and technology of energy, including geothermal energy, fossil energy, solar energy, nuclear energy, wind energy, hydro energy, bio energy, energy and the environment, energy and economics, the hydrogen economy, and energy forecasts. This broad background will give you additional flexibility during your career and help you thrive in an energy industry that is evolving from an industry dominated by fossil fuels to an industry working with many energy sources. Prerequisite: MATH213, PHGN200. 3 hours lecture; 3 semester hours.

PEGN460. FLOW IN PIPE NETWORKS. 3.0 Semester Hrs.
(II) This course will provide an introduction to single and two phase hydraulics phenomena and modeling approaches to calculate pressure/temperature profile, losses along and flow rates along a production system. Furthermore, topics related to pipeline flow control and maintenance such as leak detection, damage prevention, integrity and pipe repairs will be covered. Finally, Federal Pipeline Safety Regulations and Health, Safety, and the Environment (HSE) regulations for the transportation of gas and hazardous liquids by pipeline will be discussed. In addition, this course will provide an introduction in transient theoretical modeling and design applications. OLGA transient multiphase flow simulator will be introduced and used to complete homework and final project. Industrial practices and operational problem related to transient production design will be covered. Prerequisites: PEGN251, CHGN209 , MATH225, and PEGN305. 3 hours lecture; 3 semester hours.

PEGN461. SURFACE FACILITIES DESIGN AND OPERATION. 3.0 Semester Hrs.
(I) This course will cover surface facilities typically required in the oil and gas industry. The course provides basic operation, design and evaluation of individual equipment such as Control equipment (control valve, pressure/level/flow rate/temperature), Liquid/gas Separators, Flowmeters, Boosting Equipment (pumps, compressors), Heaters, and Storage. Basic principles are described to design and evaluate different midstream processes such as Oil/water treating, Gas/liquid and liquid/liquid separation, Crude oil stabilization, Gas handling facilities, Dehydration, Gas Sweetening, Liquefied Natural Gas (LNG), Gas to Liquids (GTL). Furthermore, potential operation problems and piping and instrumentation diagram/drawing (P&ID) related to this processes will be discussed. Calculation examples and a design project can be given to integrate all acquired knowledge. Furthermore, ASME and API norms related to material selection, equipment selection, operation and maintenance will be discussed. Finally, Health, Safety, and the Environment (HSE) regulations for midstream operations will be discussed. Course objectives include learning how to select and operate different surface equipment required in the oil and natural gas industry, learning how to monitor, troubleshoot and optimize the operation of different surface equipment required in the oil and natural gas industry. Prerequisites: PEGN251, CHGN209, MATH225, PEGN305. 3 hours lecture; 3 semester hours.

PEGN462. FLOW ASSURANCE. 3.0 Semester Hrs.
(I) This course will cover hydrocarbon production including design and operational issues. Major subjects to be covered include the prediction of hydrates formation, paraffin, asphaltene, scale and sand deposition, and remedial actions. In addition, operational problems such as slugging, emulsions and corrosion will be covered. This course will provide to student's strong background on hydraulic modeling. Prerequisites: PEGN251, CHGN209, MATH225, and PEGN305. 3 hours lecture; 3 semester hours.

PEGN463. PETROLEUM MIDSTREAM DESIGN. 3.0 Semester Hrs.
(II) This course will cover the development of an integrated project in the midstream area. In this the students will integrate the knowledge from the midstream classes to solve a given problem with consideration of social responsibility and societal impacts. The objective is to work with several companies from the midstream sector to solve field problems. Furthermore, in this class, we will have some classes to cover more specific subjects with different presenters (i.e. safety, regulations, marketing, environment, new technologies for pipe repairs or inspections, software, process to sell/buy oil, etc), field visits, etc. Prerequisites: PEGN251, PEGN305, CHGN209, and MATH225. 3 hours lecture; 3 semester hours.

PEGN481. PETROLEUM SEMINAR. 2.0 Semester Hrs.
(I) (WI) Written and oral presentations by each student on current energy topics. This course is designated as a writing intensive course (WI). Prerequisite: none. 2 hours lecture; 2 semester hours.

PEGN490. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.
(I) The course provides an introduction to fundamental rock mechanics and aims to emphasize their role in oil and gas exploration, drilling, completion and production engineering operations. Deformation as a function of stress, elastic moduli, in situ stress, stress magnitude and orientation, pore pressure, strength and fracture gradient, rock characteristic from field data (seismic, logging, drilling, production), integrated wellbore stability analysis, depletion and drilling induced fractures, compaction and associated changes in rock properties, hydraulic fracturing and fracture stability are among the topics to be covered. Pre-requisites: CEEN311. 3 hours lecture; 3 hours lab, 3 semester hours.

PEGN498. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PEGN501. APPLICATIONS OF NUMERICAL METHODS TO PETROLEUM ENGINEERING. 3.0 Semester Hrs.
The course will solve problems of interest in Petroleum Engineering through the use of spreadsheets on personal computers and structured FORTRAN programming on PCs or mainframes. Numerical techniques will include methods for numerical quadrature, differentiation, interpolation, solution of linear and nonlinear ordinary differential equations, curve fitting and direct or iterative methods for solving simultaneous equations. Prerequisites: PEGN414 and PEGN424. 3 hours lecture; 3 semester hours.

PEGN502. ADVANCED DRILLING FLUIDS. 3.0 Semester Hrs.
The physical properties and purpose of drilling fluids are investigated. Emphasis is placed on drilling fluid design, clay chemistry, testing, and solids control. Prerequisite: PEGN311. 2 hours lecture, 3 hours lab; 3 semester hours.

PEGN503. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work alone and in teams to study reservoirs from fluvial-deltaic and valley fill depositional environments. This is a multidisciplinary course that shows students how to characterize and model subsurface reservoir performance by integrating data, methods and concepts from geology, geophysics and petroleum engineering. Activities include field trips, computer modeling, written exercises and oral team presentations. Prerequisite: none. 2 hours lecture, 3 hours lab; 3 semester hours. Offered fall semester, odd years.

PEGN504. INTEGRATED EXPLORATION AND DEVELOPMENT. 3.0 Semester Hrs.
(I) Students work in multidisciplinary teams to study practical problems and case studies in integrated subsurface exploration and development. The course addresses emerging technologies and timely topics with a general focus on carbonate reservoirs. Activities include field trips, 3D computer modeling, written exercises and oral team presentation. Prerequisite: none. 3 hours lecture and seminar; 3 semester hours. Offered fall semester, even years.

PEGN505. HORIZONTAL WELLS: RESERVOIR AND PRODUCTION ASPECTS. 3.0 Semester Hrs.
This course covers the fundamental concepts of horizontal well reservoir and production engineering with special emphasis on the new developments. Each topic covered highlights the concepts that are generic to horizontal wells and draws attention to the pitfalls of applying conventional concepts to horizontal wells without critical evaluation. There is no set prerequisite for the course but basic knowledge on general reservoir engineering concepts is useful. 3 hours lecture; 3 semester hours.

PEGN506. ENHANCED OIL RECOVERY METHODS. 3.0 Semester Hrs.
Enhanced oil recovery (EOR) methods are reviewed from both the qualitative and quantitative standpoint. Recovery mechanisms and design procedures for the various EOR processes are discussed. In addition to lectures, problems on actual field design procedures will be covered. Field case histories will be reviewed. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN507. INTEGRATED FIELD PROCESSING. 3.0 Semester Hrs.
Integrated design of production facilities covering multistage separation of oil, gas, and water, multiphase flow, oil skimmers, natural gas dehydration, compression, crude stabilization, petroleum fluid storage, and vapor recovery. Prerequisite: PEGN411. 3 hours lecture; 3 semester hours.

PEGN508. ADVANCED ROCK PROPERTIES. 3.0 Semester Hrs.
Application of rock mechanics and rock properties to reservoir engineering, well logging, well completion and well stimulation. Topics covered include: capillary pressure, relative permeability, velocity effects on Darcy?s Law, elastic/mechanical rock properties, subsidence, reservoir compaction, and sand control. Prerequisites: PEGN423 and PEGN426. 3 hours lecture; 3 semester hours.

PEGN511. ADVANCED THERMODYNAMICS AND PETROLEUM FLUIDS PHASE BEHAVIOR. 3.0 Semester Hrs.
Essentials of thermodynamics for understanding the phase behavior of petroleum fluids such as natural gas and oil. Modeling of phase behavior of single and multi-component systems with equations of states with a brief introduction to PVT laboratory studies, commercial PVT software, asphaltenes, gas hydrates, mineral deposition, and statistical thermodynamics. Prerequisites: PEGN310 and PEGN305 or equivalent. 3 hours lecture; 3 semester hours.

PEGN512. ADVANCED GAS ENGINEERING. 3.0 Semester Hrs.
The physical properties and phase behavior of gas and gas condensates will be discussed. Flow through tubing and pipelines as well as through porous media is covered. Reserve calculations for normally pressured, abnormally pressured and water drive reservoirs are presented. Both stabilized and isochronal deliverability testing of gas wells will be illustrated. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN513. RESERVOIR SIMULATION I. 3.0 Semester Hrs.
The course provides the rudiments of reservoir simulation, which include flow equations, solution methods, and data requirement. Specifically, the course covers: equations of conservation of mass, conservation of momentum, and energy balance; numerical solution of flow in petroleum reservoirs by finite difference (FD) and control volume FD; permeability tensor and directional permeability; non-Darcy flow; convective flow and numerical dispersion; grid orientation problems; introduction to finite element and mixed finite-element methods; introduction to hybrid analytical/numerical solutions; introduction to multi-phase flow models; relative permeability, capillary pressure and wettability issues; linear equation solvers; streamline simulation; and multi-scale simulation concept. Prerequisite: PEGN424 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN514. PETROLEUM TESTING TECHNIQUES. 3.0 Semester Hrs.
Investigation of basic physical properties of petroleum reservoir rocks and fluids. Review of recommended practices for testing drilling fluids and oil well cements. Emphasis is placed on the accuracy and calibration of test equipment. Quality report writing is stressed. Prerequisite: Graduate status. 2 hours lecture, 1 hour lab; 3 semester hours. Required for students who do not have a BS in PE.

PEGN515. RESERVOIR ENGINEERING PRINCIPLES. 3.0 Semester Hrs.
Reservoir Engineering overview. Predicting hydrocarbon in place; volumetric method, deterministic and probabilistic approaches, material balance, water influx, graphical techniques. Fluid flow in porous media; continuity and diffusivity equations. Well performance; productivity index for vertical, perforated, fractured, restricted, slanted, and horizontal wells, inflow performance relationship under multiphase flow conditions. Combining material balance and well performance equations. Future reservoir performance prediction; Muskat, Tarner, Carter and Tracy methods. Fetkovich decline curves. Reservoir simulation; fundamentals and formulation, streamline simulation, integrated reservoir studies. 3 hours lecture, 3 semester hours.

PEGN516. PRODUCTION ENGINEERING PRINCIPLES. 3.0 Semester Hrs.
Production Engineering Overview. Course provides a broad introduction to the practice of production engineering. Covers petroleum system analysis, well stimulation (fracturing and acidizing), artificial lift (gas lift, sucker rod, ESP, and others), and surface facilities. 3 hours lecture, 3 semester hours.

PEGN517. DRILLING ENGINEERING PRINCIPLES. 3.0 Semester Hrs.
Drilling Engineering overview. Subjects to be covered include overall drilling organization, contracting, and reporting; basic drilling engineering principles and equipment; drilling fluids, hydraulics, and cuttings transport; drillstring design; drill bits; drilling optimization; fishing operations; well control; pore pressure and fracture gradients, casing points and design; cementing; directional drilling and horizontal drilling. 3 hours lecture, 3 semester hours.

PEGN519. ADVANCED FORMATION EVALUATION. 3.0 Semester Hrs.
A detailed review of wireline well logging and evaluation methods stressing the capability of the measurements to determine normal and special reservoir rock parameters related to reservoir and production problems. Computers for log processing of single and multiple wells. Utilization of well logs and geology in evaluating well performance before, during, and after production of hydrocarbons. The sensitivity of formation evaluation parameters in the volumetric determination of petroleum in reservoirs. Prerequisite: PEGN419. 3 hours lecture; 3 semester hours.

PEGN522. ADVANCED WELL STIMULATION. 3.0 Semester Hrs.
Basic applications of rock mechanics to petroleum engineering problems. Hydraulic fracturing; acid fracturing, fracturing simulators; fracturing diagnostics; sandstone acidizing; sand control, and well bore stability. Different theories of formation failure, measurement of mechanical properties. Review of recent advances and research areas. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN523. ADVANCED ECONOMIC ANALYSIS OF OIL AND GAS PROJECTS. 3.0 Semester Hrs.
Determination of present value of oil properties. Determination of severance, ad valorem, windfall profit, and federal income taxes. Analysis of profitability indicators. Application of decision tree theory and Monte Carlo methods to oil and gas properties. Economic criteria for equipment selection. Prerequisite: PEGN422 or EBGN504 or ChEN504 or MNGN427 or ChEN421. 3 hours lecture; 3 semester hours.

PEGN524. PETROLEUM ECONOMICS AND MANAGEMENT. 3.0 Semester Hrs.
Business applications in the petroleum industry are the central focus. Topics covered are: fundamentals of accounting, oil and gas accounting, strategic planning, oil and gas taxation, oil field deals, negotiations, and the formation of secondary units. The concepts are covered by forming companies that prepare proforma financial statements, make deals, drill for oil and gas, keep accounting records, and negotiate the participation formula for a secondary unit. Prerequisite: PEGN422. 3 hours lecture; 3 semester hours.

PEGN530. ENVIRONMENTAL, ENERGY, AND NATURAL RESOURCES LAW. 3.0 Semester Hrs.
Equivalent with CEEN492,CEEN592,ESGN490,ESGN502,
(II) Covered topics: a survey of United States (US) environmental law including the National Environmental Protection Act (NEPA), Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Comprehensive Environmental Response Compensation and Liability Act (CERCLA), Toxic Substances Control Act (TSCA), and Oil Pollution Act (OPA); and US law and regulation of public lands, endangered species, timber, water, minerals, coal, oil, natural gas, nuclear power, hydroelectric power, and alternative energy resources. 3 hours lecture; 3 semester hours.

PEGN541. APPLIED RESERVOIR SIMULATION. 3.0 Semester Hrs.
Concepts of reservoir simulation within the context of reservoir management will be discussed. Course participants will learn how to use available flow simulators to achieve reservoir management objectives. They will apply the concepts to an open-ended engineering design problem. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN542. INTEGRATED RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.
The course introduces integrated reservoir characterization from a petroleum engineering perspective. Reservoir characterization helps quantify properties that influence flow characteristics. Students will learn to assess and integrate data sources into a comprehensive reservoir model. Prerequisites: PEGN424. 3 hours lecture; 3 semester hours.

PEGN550. MODERN RESERVOIR SIMULATORS. 3.0 Semester Hrs.
Students will learn to run reservoir simulation software using a variety of reservoir engineering examples. The course will focus on the capabilities and operational features of simulators. Students will learn to use pre- and post-processors, fluid property analysis software, black oil and gas reservoir models, and compositional models. 3 hours lecture; 3 semester hours.

PEGN577. WORKOVER DESIGN AND PRACTICE. 3.0 Semester Hrs.
Workover Engineering overview. Subjects to be covered include Workover Economics, Completion Types, Workover Design Considerations, Wellbore Cleanout (Fishing), Workover Well Control, Tubing and Workstring Design, SlicklineOperations, Coiled Tubing Operations, Packer Selection, Remedial Cementing Design and Execution, Completion Fluids, Gravel Packing, and Acidizing. 3 hours lecture, 3 semester hours.

PEGN590. RESERVOIR GEOMECHANICS. 3.0 Semester Hrs.
The course provides an introduction to fundamental rock mechanics concepts and aims to emphasize their role in exploration, drilling, completion and production engineering operations. Basic stress and strain concepts, pore pressure, fracture gradient and in situ stress magnitude and orientation determination and how these properties are obtained from the field measurements, mechanisms of deformation in rock, integrated wellbore stability analysis, depletion induced compaction and associated changes in rock properties and formation strength, hydraulic fracturing and fracture stability are among the topics to be covered in this rock course. Naturally fractured formation properties and how they impact the characteristics measured in the laboratory and in field are also included in the curriculum. Several industry speakers are invited as part of the lecture series to bring practical aspects of the fundamentals of geomechanics covered in the classroom. In addition, Petrel, FLAC3D and FRACMAN software practices with associated assignments are offered to integrate field data on problems including in situ stress magnitude and orientations, pore pressure and fracture gradient prediction and rock property determination using laboratory core measurements, logs, seismic, geological data. Problems are assign for students to use the field and laboratory data to obtain static and dynamic moduli, rock failure criteria, wellbore stress concentration and failure, production induced compaction/subsidence and hydraulic fracture mechanics.

PEGN591. SHALE RESERVOIR ENGINEERING. 3.0 Semester Hrs.
Equivalent with PEGN615,
Fundamentals of shale-reservoir engineering and special topics of production from shale reservoirs are covered. The question of what makes shale a producing reservoir is explored. An unconventional understanding of shale-reservoir characterization is emphasized and the pitfalls of conventional measurements and interpretations are discussed. Geological, geomechanical, and engineering aspects of shale reservoirs are explained. Well completions with emphasis on hydraulic fracturing and fractured horizontal wells are discussed from the viewpoint of reservoir engineering. Darcy flow, diffusive flow, and desorption in shale matrix are covered. Contributions of hydraulic and natural fractures are discussed and the stimulated reservoir volume concept is introduced. Interactions of flow between fractures and matrix are explained within the context of dual-porosity modeling. Applications of pressure-transient, rate-transient, decline-curve and transient-productivity analyses are covered. Field examples are studied. 3 hours lecture; 3 semester hours.

PEGN592. GEOMECHANICS FOR UNCONVENTIONAL RESOURCES. 3.0 Semester Hrs.
A wide spectrum of topics related to the challenges and solutions for the exploration, drilling, completion, production and hydraulic fracturing of unconventional resources including gas and oil shale, heavy oil sand and carbonate reservoirs, their seal formations is explored. The students acquire skills in integrating and visualizing multidiscipline data in Petrel (a short tutorial is offered) as well as assignments regarding case studies using field and core datasets. The role of integrating geomechanics data in execution of the exploration, drilling, completion, production, hydraulic fracturing and monitoring of pilots as well as commercial applications in unlocking the unconventional resources are pointed out using examples. Prerequisite: PEGN590. 3 hours lecture; 3 semester hours.

PEGN593. ADVANCED WELL INTEGRITY. 3.0 Semester Hrs.
Fundamentals of wellbore stability, sand production, how to keep wellbore intact is covered in this course. The stress alterations in near wellbore region and associated consequences in the form of well failures will be covered in detailed theoretically and with examples from deepwater conventional wells and onshore unconventionalwell operations. Assignments will be given to expose the students to the real field data to interpret and evaluate cases to determinepractical solutions to drilling and production related challenges. Fluid pressure and composition sensitivity of various formations will be studied. 3 hours lecture; 3 semester hours.

PEGN594. ADVANCED DIRECTIONAL DRILLING. 3.0 Semester Hrs.
Application of directional control and planning to drilling. Major topics covered include: Review of procedures for the drilling of directional wells. Section and horizontal view preparation. Two and three dimensional directional planning. Collision diagrams. Surveying and trajectory calculations. Surface and down hole equipment. Common rig operating procedures, and horizontal drilling techniques. Prerequisite: PEGN311 or equivalent. 3 hours lecture; 3 semester hours.

PEGN595. DRILLING OPERATIONS. 3.0 Semester Hrs.
Lectures, seminars, and technical problems with emphasis on well planning, rotary rig supervision, and field practices for execution of the plan. This course makes extensive use of the drilling rig simulator. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN596. ADVANCED WELL CONTROL. 3.0 Semester Hrs.
Principles and procedures of pressure control are taught with the aid of a full-scale drilling simulator. Specifications and design of blowout control equipment for onshore and offshore drilling operations, gaining control of kicks, abnormal pressure detection, well planning for wells containing abnormal pressures, and kick circulation removal methods are taught. Students receive hands-on training with the simulator and its peripheral equipment. Prerequisite: PEGN311. 3 hours lecture; 3 semester hours.

PEGN597. TUBULAR DESIGN. 3.0 Semester Hrs.
Fundamentals of tubulars (casing, tubing, and drill pipe) design applied to drilling. Major topics covered include: Dogleg running loads. Directional hole considerations. Design criteria development. Effects of formation pressures. Stability loads after cementing. Effects of temperature, pressure, mud weights, and cement. Helical bending of tubing. Fishing loads. Micro-annulus problem. Strengths of API tubulars. Abrasive wear while rotating drill pipe. How to design for hydrogen sulfide and fatigue corrosion. Connection selection. Common rig operating procedures. Prerequisites: PEGN311 and PEGN361 or equivalent. 3 hours lecture; 3 semester hours.

PEGN598. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN601. APPLIED MATHEMATICS OF FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.
This course is intended to expose petroleum-engineering students to the special mathematical techniques used to solve transient flow problems in porous media. Bessel?s equation and functions, Laplace and Fourier transformations, the method of sources and sinks, Green? s functions, and boundary integral techniques are covered. Numerical evaluation of various reservoir engineering solutions, numerical Laplace transformation and inverse transformation are also discussed. 3 hours lecture; 3 semester hours.

PEGN603. DRILLING MODELS. 3.0 Semester Hrs.
Analytical models of physical phenomena encountered in drilling. Casing and drilling failure from bending, fatigue, doglegs, temperature, stretch; mud filtration; corrosion; wellhead loads; and buoyancy of tubular goods. Bit weight and rotary speed optimization. Prerequisites: PEGN311 and PEGN361. 3 hours lecture; 3 semester hours.

PEGN604. INTEGRATED FLOW MODELING. 3.0 Semester Hrs.
Students will study the formulation, development and application of a reservoir flow simulator that includes traditional fluid flow equations and a petrophysical model. The course will discuss properties of porous media within the context of reservoir modeling, and present the mathematics needed to understand and apply the simulator. Simulator applications will be interspersed throughout the course. 3 hours lecture; 3 semester hours.

PEGN605. WELL TESTING AND EVALUATION. 3.0 Semester Hrs.
Various well testing procedures and interpretation techniques for individual wells or groups of wells. Application of these techniques to field development, analysis of well problems, secondary recovery, and reservoir studies. Productivity, gas well testing, pressure buildup and drawdown, well interference, fractured wells, type curve matching, and shortterm testing. Prerequisite: PEGN426. 3 hours lecture; 3 semester hours.

PEGN606. ADVANCED RESERVOIR ENGINEERING. 3.0 Semester Hrs.
A review of depletion type, gas-cap, and volatile oil reservoirs. Lectures and supervised studies on gravity segregation, moving gas-oil front, individual well performance analysis, history matching, performance prediction, and development planning. Prerequisite: PEGN423. 3 hours lecture; 3 semester hours.

PEGN607. PARTIAL WATER DRIVE RESERVOIRS. 3.0 Semester Hrs.
The hydrodynamic factors which influence underground water movement, particularly with respect to petroleum reservoirs. Evaluation of oil and gas reservoirs in major water containing formations. Prerequisite: PEGN424. 3 hours lecture; 3 semester hours.

PEGN608. MULTIPHASE FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.
The factors involved in multiphase fluid flow in porous and fractured media. Physical processes and mathematical models for micro- and macroscopic movement of multiphase fluids in reservoirs. Performance evaluation of various displacement processes in the laboratory as well as in the petroleum field during the secondary and EOR/IOR operations. Prerequisite: PEGN 424, 3 hours lecture; 3 semester hours.

PEGN614. RESERVOIR SIMULATION II. 3.0 Semester Hrs.
The course reviews the rudiments of reservoir simulation and flow equations, solution methods, and data requirement. The course emphasizes multi-phase flow and solution techniques; teaches the difference between conventional reservoir simulation, compositional modeling and multi-porosity modeling; teaches how to construct three-phase relative permeability from water-oil and gas-oil relative permeability data set; the importance of capillary pressure measurements and wetability issues; discusses the significance of gas diffusion and interphase mass transfer. Finally, the course develops solution techniques to include time tested implicit-pressure-explicitsaturation, sequential and fully implicit methods. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 credit hours. 3 hours of lecture per week.

PEGN619. GEOMECHANICALLY AND PHYSICOCHEMICALLY COUPLED FLUID FLOW IN POROUS MEDIA. 3.0 Semester Hrs.
The role of physic-chemisty and geomechanics on fluid flow in porous media will be included in addition to conventional fluid flow modeling and measurmeents in porous media. The conventional as well as unconventional reservoirs will be studied with the coupling of physicochemical effects and geomechanics stresses. Assignments will be given to expose the students to the real field data in interpretation and evaluation of filed cases to determine practical solutions to drilling and production related modeling challenges. 3 hours lecture; 3 semester hours.

PEGN620. NATURALLY FRACTURED RESERVOIRS -- ENGINEERING AND RESERVOIR SIMULATION. 3.0 Semester Hrs.
The course covers reservoir engineering, well testing, and simulation aspects of naturally fractured reservoirs. Specifics include: fracture description, connectivity and network; fracture properties; physical principles underlying reservoir engineering and modeling naturally fractured reservoirs; local and global effects of viscous, capillary, gravity and molecular diffusion flow; dual-porosity/dual-permeability models; multi-scale fracture model; dual-mesh model; streamlin model; transient testing with non-Darcy flow effects; tracer injection and breakthrough analysis; geomechanics and fractures; compositional model; coal-bed gas model; oil and gas from fractured shale; improved and enhanced oil recovery in naturally fracture reservoirs. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN624. COMPOSITIONAL MODELING - APPLICATION TO ENHANCED OIL RECOVERY. 3.0 Semester Hrs.
Efficient production of rich and volatile oils as well as enhanced oil recovery by gas injection (lean and rich natural gas, CO2, N2, air, and steam) is of great interest in the light of greater demand for hydrocarbons and the need for CO2 sequestration. This course is intended to provide technical support for engineers dealing with such issues. The course begins with a review of the primary and secondary recovery methods, and will analyze the latest worldwide enhanced oil recovery production statistics. This will be followed by presenting a simple and practical solvent flooding model to introduce the student to data preparation and code writing. Next, fundamentals of phase behavior, ternary phase diagram, and the Peng-Robinson equation of state will be presented. Finally, a detailed set of flow and thermodynamic equations for a full-fledged compositional model, using molar balance, equation of motion and the afore-mentioned equation of state, will be developed and solution strategy will be presented. Prerequisite: PEGN513 or equivalent, strong reservoir engineering background, and basic computer programming knowledge. 3 hours lecture; 3 semester hours.

PEGN660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION. 3.0 Semester Hrs.
Equivalent with GEOL660,
(II) This course will include keynote lectures and seminars on the reservoir characterization of carbonate rocks, including geologic description, petrophysics and production engineering. Course will focus on the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises, that include a reflection seismic, well log, and core data. 3 hours lecture; 3 semester hours.

PEGN681. PETROLEUM ENGINEERING SEMINAR. 3.0 Semester Hrs.
Comprehensive reviews of current petroleum engineering literature, ethics, and selected topics as related to research and professionalism. 3 hours seminar; 3 semester hour.

PEGN698. SPECIAL TOPICS IN PETROLEUM ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

PHYSICAL ACTIVITIES (PAGN)

PAGN101. PHYSICAL EDUCATION. 0.5 Semester Hrs.
(I) A general overview of life fitness basics which includes exposure to educational units of Nutrition, Stress Management, Drug and Alcohol Awareness. Instruction in Fitness units provides the student an opportunity for learning and the beginning basics for a healthy life style. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN102. PHYSICAL EDUCATION. 0.5 Semester Hrs.
(II) Sections in physical fitness and team sports, relating to personal health and wellness activities. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN133. OUTDOOR LEADERSHIP. 0.5 Semester Hrs.
(I, II) This Outdoor Leadership course is set to involve many students in experiencing outdoors and leadership in a combined manner. Outdoor programs require a high level of skill development, team work, real-time feedback loops, planning, monitoring of team members and outdoor conditions. Outdoor skills allow people access to more opportunities for relaxation, travel, personal exploration. Leadership and followership skills come through working with other people, time management, forming alternate plans, and then evaluating decisions. Repeatable for credit. 1.50 hours lab; .50 semester hours.

PAGN151. VARSITY BASEBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of baseball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN153. VARSITY MEN'S BASKETBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of men's basketball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN154. VARSITY WOMEN'S BASKETBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of women's basketball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN157. VARSITY CROSS COUNTRY. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of cross country in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN159. VARSITY FOOTBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of football in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN161. VARSITY GOLF. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of golf in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN167. VARSITY MEN'S SOCCER. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of men's soccer in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN168. VARSITY WOMEN'S SOCCER. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of women's soccer in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN169. VARSITY SWIMMING. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of swimming and diving in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN173. VARSITY TRACK AND FIELD. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of track and field in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN175. VARSITY WRESTLING. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of wrestling in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN177. VARSITY VOLLEYBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of volleyball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN179. VARSITY SOFTBALL. 1.0 Semester Hr.
(I, II) Instruction and practice in fundamentals and mechanics of softball in preparation for collegiate competition. Satisfactory completion of any course fulfills one semester of physical education requirements. 3 hours lab; 1 semester hour. Repeatable for credit.

PAGN198. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

PAGN201. PERSONAL WELLNESS. 0.5 Semester Hrs.
(I, II) Provides an overview of the 5 Dimensions of Wellness: Physical, Social, Emotional, Intellectual and Spiritual. Students will take a proactive approach to developing strategies for optimum wellness including goal setting and application of wellness principles through assignments and group in-class work. 2 hours lecture; 0.5 semester hours. Not repeatable for credit.

PAGN202. INDOOR SOCCER. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN203. TECHNIQUES OF RELAXATION. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; .5 semester hours. Repeatable for credit.

PAGN204. FLY FISHING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN205. BEGINNING KARATE. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN206. INTERMEDIATE KARATE. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN207. TRAIL RUNNING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN208. KAYAKING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN209. AIKIDO. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN210. HIKING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN211. BEGINNING SWIMMING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN212. INTERMEDIATE SWIMMING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN221. BEGINNING WEIGHT TRAINING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN222. ADVANCED WEIGHT TRAINING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN223. DISTANCE RUNNING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN232. YOGA. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN233. OUTDOOR LEADERSHIP ADVANCED. 0.5 Semester Hrs.
(I, II) This Outdoor Leadership course is set to involve many students in experiencing outdoors and leadership in a combined manner. Outdoor programs require a high level of skill development, team work, real-time feedback loops, planning, monitoring of team members and outdoor conditions. Outdoor skills allow people access to more opportunities for relaxation, travel, personal exploration. Leadership and followership skills come through working with other people, time management, forming alternate plans, and then evaluating decisions. Repeatable for credit. 1.50 hours lab; .50 semester hours.

PAGN235. WORKOUTS AND WELLNESS. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN241. WOMEN'S WEIGHT TRAINING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN242. WOMEN'S RAQUETBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN251. GOLF. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN255. MOUNTAIN BIKING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN257. INTRODUCTION TO ROCK CLIMBING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN258. WOMEN'S ROCK CLIMBING. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN271. BEGINNING BADMINTON. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN272. ADVANCED BADMINTON. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN273. BEGINNING BASKETBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN274. ADVANCED BASKETBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN275. VOLLEYBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN277. BEGINNING RACQUETBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN279. HANDBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN280. CLUB SPORTS. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN281. ADVANCED HANDBALL. 0.5 Semester Hrs.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN285. PHYSICAL ACTIVITY. 0.5 Semester Hrs.
(S) Physical activity instruction by permission only. 2 hours lab; 0.5 semester hours. Repeatable for credit.

PAGN298. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I,II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 0.5 to 6 semester hours. Repeatable for credit under different titles.

PAGN299. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II) Students enrolling in these courses may be required to furnish their own equipment. Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ? Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PAGN398. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I,II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 0.5 to 6 credit hours. Repeatable for credit under different titles.

PAGN498. SPECIAL TOPICS. 0.5-6 Semester Hr.
(I,II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Variable credit; 0.5 to 6 credit hours. Repeatable for credit under different titles.

PHYSICS (PHGN)

PHGN100. PHYSICS I - MECHANICS. 4.5 Semester Hrs.
(I,II,S) A first course in physics covering the basic principles of mechanics using vectors and calculus. The course consists of a fundamental treatment of the concepts and applications of kinematics and dynamics of particles and systems of particles, including Newton's laws, energy and momentum, rotation, oscillations, and waves. Prerequisite: MATH111. Co-requisites: MATH112 or MATH113 or MATH122. 2 hours lecture; 4 hours studio; 4.5 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-SC1.

PHGN198. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN199. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN200. PHYSICS II-ELECTROMAGNETISM AND OPTICS. 4.5 Semester Hrs.
(I, II, S) Continuation of PHGN100. Introduction to the fundamental laws and concepts of electricity and magnetism, electromagnetic devices, electromagnetic behavior of materials, applications to simple circuits, electromagnetic radiation, and an introduction to optical phenomena. Prerequisite: Grade of C- or higher in PHGN100, concurrent enrollment in MATH213 or MATH214 or MATH223. 2 hours lecture; 4 hours studio; 4.5 semester hours.

PHGN215. ANALOG ELECTRONICS. 4.0 Semester Hrs.
(II) Introduction to analog devices used in modern electronics and basic topics in electrical engineering. Introduction to methods of electronics measurements, particularly the application of oscilloscopes and computer based data acquisition. Topics covered include circuit analysis, electrical power, diodes, transistors (FET and BJT), operational amplifiers, filters, transducers, and integrated circuits. Laboratory experiments in the use of basic electronics for physical measurements. Emphasis is on practical knowledge gained in the laboratory, including prototyping, troubleshooting, and laboratory notebook style. Prerequisite: PHGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

PHGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN300. PHYSICS III-MODERN PHYSICS I. 3.0 Semester Hrs.
Equivalent with PHGN310,
(I) Our technical world is filled with countless examples of modern physics. This course will discuss some historic experiments that led to the key discoveries, and the basic concepts, theories, and models behind some of our present day technologies. Topics may include special relativity, quantum physics, atomic and molecular physics, solid-state physics, semiconductor theory and devices, nuclear physics, particle physics and cosmology. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

PHGN310. HONORS PHYSICS III-MODERN PHYSICS. 3.0 Semester Hrs.
Equivalent with PHGN300,
(II) The third course in introductory physics with in depth discussion on special relativity, wave-particle duality, the Schroedinger equation, electrons in solids, quantum tunneling, nuclear structure and transmutations. Registration is strongly recommended for declared physics majors and those considering majoring or minoring in physics. Prerequisite: PHGN200; Concurrent enrollment in MATH225. 3 hours lecture; 3 semester hours.

PHGN311. INTRODUCTION TO MATHEMATICAL PHYSICS. 3.0 Semester Hrs.
(I) Demonstration of the unity of diverse topics such as mechanics, quantum mechanics, optics, and electricity and magnetism via the techniques of linear algebra, complex variables, Fourier transforms, and vector calculus. Prerequisites: PHGN300 or PHGN310, MATH225, MATH332, and CSCI250. 3 hours lecture; 3 semester hours.

PHGN315. ADVANCED PHYSICS LAB I. 2.0 Semester Hrs.
(I) (WI) Introduction to laboratory measurement techniques as applied to modern physics experiments. Experiments from optics and atomic physics. A writing-intensive course with laboratory and computer design projects based on applications of modern physics. Prerequisite: PHGN300/310, PHGN384. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN317. SEMICONDUCTOR CIRCUITS- DIGITAL. 3.0 Semester Hrs.
(I) Introduction to digital devices used in modern electronics. Topics covered include logic gates, flip-flops, timers, counters, multiplexing, analog-to-digital and digital-to-analog devices. Emphasis is on practical circuit design and assembly. Prerequisite: PHGN215 and CSCI250. 2 hours lecture; 3 hours lab; 3 semester hours.

PHGN320. MODERN PHYSICS II: BASICS OF QUANTUM MECHANICS. 4.0 Semester Hrs.
(II) Introduction to the Schroedinger theory of quantum mechanics. Topics include Schroedinger's equation, quantum theory of measurement, the uncertainty principle, eigenfunctions and energy spectra, anular momentum, perturbation theory, and the treatment of identical particles. Example applications taken from atomic, molecular, solid state or nuclear systems. Prerequisites: PHGN300 or PHGN310 and PHGN311. 4 hours lecture; 4 semester hours.

PHGN324. INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS. 3.0 Semester Hrs.
(II) Celestial mechanics; Kepler's laws and gravitation; solar system and its contents; electromagnetic radiation and matter; stars: distances, magnitudes, spectral classification, structure, and evolution. Variable and unusual stars, pulsars and neutron stars, supernovae, black holes, and models of the origin and evolution of the universe. Prerequisite: PHGN200. 3 hours lecture; 3 semester hours.

PHGN326. ADVANCED PHYSICS LAB II. 2.0 Semester Hrs.
(II) (WI) Continuation of PHGN315. A writing-intensive course which expands laboratory experiments to include nuclear and solid state physics. Prerequisite: PHGN315. 1 hour lecture, 3 hours lab; 2 semester hours.

PHGN340. COOPERATIVE EDUCATION. 1-3 Semester Hr.
(I, II, S) Supervised, full-time, engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00. 1 to 3 semester hours. Repeatable up to 3 credit hours.

PHGN341. THERMAL PHYSICS. 3.0 Semester Hrs.
(II) An introduction to statistical physics from the quantum mechanical point of view. The microcanonical and canonical ensembles. Heat, work and the laws of thermodynamics. Thermodynamic potentials; Maxwell relations; phase transformations. Elementary kinetic theory. An introduction to quantum statistics. Prerequisite: CHGN122 or CHGN125 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN350. INTERMEDIATE MECHANICS. 4.0 Semester Hrs.
(I) Begins with an intermediate treatment of Newtonian mechanics and continues through an introduction to Hamilton's principle and Hamiltonian and Lagrangian dynamics. Includes systems of particles, linear and driven oscillators, motion under a central force, two-particle collisions and scattering, motion in non-inertial reference frames and dynamics of rigid bodies.Prerequisite:PHGN200. Corequisite: PHGN311. 4 hours lecture; 4 semester hours.

PHGN361. INTERMEDIATE ELECTROMAGNETISM. 3.0 Semester Hrs.
(II) Theory and application of the following: static electric and magnetic fields in free space, dielectric materials, and magnetic materials; steady currents; scalar and vector potentials; Gauss' law and Laplace's equation applied to boundary value problems; Ampere's and Faraday's laws. Prerequisite: PHGN200 and PHGN311. 3 hours lecture; 3 semester hours.

PHGN384. FIELD SESSION TECHNIQUES IN PHYSICS. 1-6 Semester Hr.
(S) Introduction to the design and fabrication of engineering physics apparatus. Intensive individual participation in the design of machined system components, vacuum systems, electronics, optics, and application of computer interfacing systems and computational tools. Supplementary lectures on safety, laboratory techniques and professional development. Visits to regional research facilities and industrial plants. Prerequisites: PHGN300 or PHGN310, PHGN215, CSCI250. 6 semester hours.

PHGN398. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN401. THEORETICAL PHYSICS SEMINAR. 1.0 Semester Hr.
(I,II) Students will attend the weekly theoretical physics seminar. Students will be responsible for presentation and discussion. Corequisite: PHGN300/PHGN310. 1 hour lecture; 1 semester hour.

PHGN418. GENERAL RELATIVITY. 3.0 Semester Hrs.
(II) Introduction to Einstein's theory of gravitation. Requisite mathematics introduced and developed including tensor calculus and differential geometry. Formulation of Einstein field and geodesic equations. Development and analysis of solutions including stellar, black hole and cosmological geometries. Prerequisite: PHGN350. 3 hours lecture; 3 semester hours.

PHGN419. PRINCIPLES OF SOLAR ENERGY SYSTEMS. 3.0 Semester Hrs.
Review of the solar resource and components of solar irradiance; principles of photovoltaic devices and photovoltaic system design; photovoltaic electrical energy production and cost analysis of photovoltaic systems relative to fossil fuel alternatives; introduction to concentrated photovoltaic systems and manufacturing methods for wafer-based and thin film photovoltaic panels. Prerequisite: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

PHGN422. NUCLEAR PHYSICS. 3.0 Semester Hrs.
Introduction to subatomic (particle and nuclear) phenomena. Characterization and systematics of particle and nuclear states; symmetries; introduction and systematics of the electromagnetic, weak, and strong interactions; systematics of radioactivity; liquid drop and shell models; nuclear technology. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN423. PARTICLE PHYSICS. 3.0 Semester Hrs.
(II) Introduction to the Standard Model of particle physics including: experimental methods, motivation and evaluation of amplitudes from Feynman diagrams with applications to scattering cross-sections and decay rates, organization of interactions based on underlying gauge-symmetry principles, Dirac equation and relativistic spinors, C, P and T symmetries, renormalization, spontaneous symmetry breaking and the Higgs mechanism for mass generation. Prerequisites: PHGN350. Co-requisites: PHGN320. 3 hour lecture.

PHGN424. ASTROPHYSICS. 3.0 Semester Hrs.
(II) A survey of fundamental aspects of astrophysical phenomena, concentrating on measurements of basic stellar properties such as distance, luminosity, spectral classification, mass, and radii. Simple models of stellar structure evolution and the associated nuclear processes as sources of energy and nucleosynthesis. Introduction to cosmology and physics of standard big-bang models. Prerequisite: PHGN300/310. 3 hours lecture; 3 semester hours.

PHGN433. BIOPHYSICS. 3.0 Semester Hrs.
Equivalent with BELS333,PHGN333,
(II) This course is designed to show the application of physics to biology. It will assess the relationships between sequence structure and function in complex biological networks and the interfaces between physics, chemistry, biology and medicine. Topics include: biological membranes, biological mechanics and movement, neural networks, medical imaging basics including optical methods, MRI, isotopic tracers and CT, biomagnetism and pharmacokinetics. Prerequisites: CBEN110. 3 hours lecture; 3 semester hours.

PHGN435. INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with CBEN435,CBEN535,CHEN435,CHEN535,MLGN535,PHGN535,
Application of science and engineering principles to the design, fabrication, and testing of microelectronic devices. Emphasis on specific unit operations and the interrelation among processing steps. Prerequisites: Senior standing in PHGN, CHGN, MTGN, or EGGN. 1.5 hours lecture, 4 hours lab; 3 semester hours.

PHGN440. SOLID STATE PHYSICS. 3.0 Semester Hrs.
An elementary study of the properties of solids including crystalline structure and its determination, lattice vibrations, electrons in metals, and semiconductors. (Graduate students in physics may register only for PHGN440.) Prerequisite: PHGN320. 3 hours lecture; 3 semester hours.

PHGN441. SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA. 3.0 Semester Hrs.
Continuation of PHGN440/ MLGN502 with an emphasis on applications of the principles of solid state physics to practical properties of materials including: optical properties, superconductivity, dielectric properties, magnetism, noncrystalline structure, and interfaces. (Graduate students in physics may register only for PHGN441.) Prerequisite: PHGN440 or MLGN502. 3 hours lecture; 3 semester hours.

PHGN450. COMPUTATIONAL PHYSICS. 3.0 Semester Hrs.
Introduction to numerical methods for analyzing advanced physics problems. Topics covered include finite element methods, analysis of scaling, efficiency, errors, and stability, as well as a survey of numerical algorithms and packages for analyzing algebraic, differential, and matrix systems. The numerical methods are introduced and developed in the analysis of advanced physics problems taken from classical physics, astrophysics, electromagnetism, solid state, and nuclear physics. Prerequisites: Introductory-level knowledge of C, Fortran, or Basic; and PHGN311. 3 hours lecture; 3 semester hours.

PHGN462. ELECTROMAGNETIC WAVES AND OPTICAL PHYSICS. 3.0 Semester Hrs.
(I) Solutions to the electromagnetic wave equation are studied, including plane waves, guided waves, refraction, interference, diffraction and polarization; applications in optics; imaging, lasers, resonators and wave guides. Prerequisite: PHGN361. 3 hours lecture; 3 semester hours.

PHGN466. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.
Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimization, diffraction, linear systems and optical transfer functions, detectors and optical system examples. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN471. SENIOR DESIGN PRINCIPLES I. 0.5 Semester Hrs.
(I) (WI) The first of a two semester sequence covering the principles of project design. Class sessions cover effective team organization, project planning, time management, literature research methods, record keeping, fundamentals of technical writing, professional ethics, project funding and intellectual property. Prerequisites: PHGN384 and PHGN326. Co-requisites: PHGN481 or PHGN491. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN472. SENIOR DESIGN PRINCIPLES II. 0.5 Semester Hrs.
(II) (WI) Continuation of PHGN471. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN482 or PHGN492. 1 hour lecture in 7 class sessions; 0.5 semester hours.

PHGN480. LASER PHYSICS. 3.0 Semester Hrs.
(I) Theory and application of the following: Interaction of light with atoms: absorption, gain, rate equations and line broadening. Propagation, control and measurement of light waves: Gaussian beams, optical resonators and wave guides, interferometers. Laser design and operation: pumping, oscillation, and dynamics (Q-switching and mode-locking). Introduction to ultrafast optics. Laboratory: alignment and characterization of laser systems. Prerequisites: PHGN320. Co-requisites: PHGN462. 3 hours lecture; 3 semester hours.

PHGN481. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(I) (WI) The first of a two semester program covering the full spectrum of project design, drawing on all of the student's previous course work. At the beginning of the first semester, the student selects a research project in consultation with the Senior Design Oversight Committee (SDOC) and the Project Mentor. The objectives of the project are given to the student in broad outline form. The student then designs the entire project, including any or all of the following elements as appropriate: literature search, specialized apparatus or algorithms, block-diagram electronics, computer data acquisition and/or analysis, sample materials, and measurement and/or analysis sequences. The course culminates in a formal interim written report. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN471. 6 hour lab; 2.5 semester hours.

PHGN482. SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(II) (WI) Continuation of PHGN481. The course culminates in a formal written report and poster. Prerequisite: PHGN384 and PHGN326. Co-requisite: PHGN472. 6 hour lab; 2.5 semester hours.

PHGN491. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(I) (WI) Individual work on an advanced research topic that involves more challenging demands than a regular senior design project. Honors students will devote more time to their project, and will produce an intermediate report in a more advanced format. Prerequisite: PHGN384 and PHGN326. Corequisite: PHGN471. 7.5 hour lab; 2.5 semester hours.

PHGN492. HONORS SENIOR DESIGN PRACTICE. 2.5 Semester Hrs.
(II) (WI) Continuation of PHGN481 or PHGN491. The course culminates in a formal written report and poster. The report may be in the form of a manuscript suitable for submission to a professional journal. Prerequisite: PHGN481 or PHGN491. Corequisite: PHGN472. 7.5 hour lab; 2.5 semesterhours.

PHGN498. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Prerequisite: none. Credit to be determined by instructor, maximum of 6 credit hours. Repeatable for credit under different titles.

PHGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
(I,II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

PHGN501. GRADUATE SEMINAR. 1.0 Semester Hr.
(I) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN502. GRADUATE SEMINAR. 1.0 Semester Hr.
(II) M.S. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN503. RESPONSIBLE CONDUCT OF RESEARCH. 1.0 Semester Hr.
(II) This course introduces students to the various components of responsible research practices. Subjects covered move from issues related to professional rights and obligations through those related to collaboration, communication and the management of grants, to issues dealing with intellectual property. The course culminates with students writing an ethics essay based on a series of topics proposed by the course instructor. 1 hour lecture; 1 semester hour.

PHGN504. RADIATION DETECTION AND MEASUREMENT. 3.0 Semester Hrs.
Physical principles and methodology of the instrumentation used in the detection and measurement of ionizing radiation. Prerequisite: none. 3 hours lecture; 3 semester hours.

PHGN505. CLASSICAL MECHANICS I. 3.0 Semester Hrs.
(I) Review of Lagrangian and Hamiltonian formulations in the dynamics of particles and rigid bodies; kinetic theory; coupled oscillations and continuum mechanics; fluid mechanics. Prerequisite: PHGN350 or equivalent. 3 hours lecture; 3 semester hours.

PHGN507. ELECTROMAGNETIC THEORY I. 3.0 Semester Hrs.
(II) To provide a strong background in electromagnetic theory. Electrostatics, magnetostatics, dynamical Maxwell equations, wave phenomena. Prerequisite: PHGN462 or equivalent and PHGN511. 3 hours lecture; 3 semester hours.

PHGN511. MATHEMATICAL PHYSICS. 3.0 Semester Hrs.
(I) Review of complex variable and finite and infinite-dimensional linear vector spaces. Sturm-Liouville problem, integral equations, computer algebra. Prerequisite: PHGN311 or equivalent. 3 hours lecture; 3 semester hours.

PHGN520. QUANTUM MECHANICS I. 3.0 Semester Hrs.
(II) Schroedinger equation, uncertainty, change of representation, one-dimensonal problems, axioms for state vectors and operators, matrix mechanics, uncertainty relations, time-independent perturbation theory, time-dependent perturbations, harmonic oscillator, angular momentum; semiclassical methods, variational methods, two-level system, sudden and adiabatic changes, applications. Prerequisite: PHGN511 and PHGN320 or equivalent. 3 hours lecture; 3 semester hours.

PHGN521. QUANTUM MECHANICS II. 3.0 Semester Hrs.
(I) Review of angular momentum, central potentials and applications. Spin; rotations in quantum mechanics. Formal scattering theory, Born series, partial wave analysis. Addition of angular momenta, Wigner-Eckart theorem, selection rules, identical particles. Prerequisite: PHGN520. 3 hours lecture; 3 semester hours.

PHGN530. STATISTICAL MECHANICS. 3.0 Semester Hrs.
(I) Review of thermodynamics; equilibrium and stability; statistical operator and ensemblesl ideal systems; phase transitions; non-equilibrium systems. Prerequisite: PHGN341 or equivalent and PHGN520. Co-requisite: PHGN521. 3 hours lecture; 3 semester hours.

PHGN535. INTERDISCIPLINARY SILICON PROCESSING LABORATORY. 3.0 Semester Hrs.
Equivalent with
CBEN435,CBEN535,CHEN435,CHEN535,MLGN535,PHGN435,
(II) Explores the application of science and engineering principles to the fabrication and testing of microelectronic devices with emphasis on specific unit operations and interrelation among processing steps. Teams work together to fabricate, test, and optimize simple devices. Prerequisite: none. 1 hour lecture, 4 hours lab; 3 semester hours.

PHGN542. SOLID STATE DEVICES AND PHOTOVOLTAIC APPLICATIONS. 3.0 Semester Hrs.
(II) An overview of the physical principles involved in the characterization, and operation of solid state devices. Topics will include: semiconductor physics, electronic transport, recombination and generation, intrinsic and extrinsic semiconductors, electrical contacts, p-n junction devices (e.g., LEDs, solar cells, lasers, particle detectors); other semiconductor devices (e.g., bipolar junction transistors and field effect transistors and capacitors). There will be emphasis on optical interactions and application to photovoltaic devices. Prerequisite: PHGN440 or equivalent. 3 hours lecture; 3 semester hours.

PHGN550. NANOSCALE PHYSICS AND TECHNOLOGY. 3.0 Semester Hrs.
An introduction to the basic physics concepts involved in nanoscale phenomena, processing methods resulting in engineered nanostructures, and the design and operation of novel structures and devices which take advantage of nanoscale effects. Students will become familiar with interdisciplinary aspects of nanotechnology, as well as with current nanoscience developments described in the literature. Prerequisites: PHGN320, PHGN341, co-requisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN566. MODERN OPTICAL ENGINEERING. 3.0 Semester Hrs.
Provides students with a comprehensive working knowledge of optical system design that is sufficient to address optical problems found in their respective disciplines. Topics include paraxial optics, imaging, aberration analysis, use of commercial ray tracing and optimazation, diffraction, linear systems and optical transfer functions, detectors, and optical system examples. Prerequisite: PHGN462. 3 hours lecture; 3 semester hours.

PHGN570. FOURIER AND PHYSICAL OPTICS. 3.0 Semester Hrs.
This course addresses the propagation of light through optical systems. Diffraction theory is developed to show how 2D Fourier transforms and linear systems theory can be applied to imaging systems. Analytic and numerical Fourier and microscopes, spectrometers and holographic imaging. They are also applied to temporal propagation in ultrafast optics. Prerequisite: PHGN462 or equivalent. 3 hours lecture; 3 semester hours.

PHGN585. NONLINEAR OPTICS. 3.0 Semester Hrs.
An exploration of the nonlinear response of a medium (semiclassical and quantum descriptions) and nonlinear wave mixing and propagation. Analytic and numeric techniques to treat nonlinear dynamics are developed. Applications to devices and modern research areas are discussed, including harmonic and parametric wave modulation, phase conjugation, electro-optic modulation. Prerequiste: PHGN462 or equivalent, PHGN520. 3 hours lecture; 3 semester hours.

PHGN590. NUCLEAR REACTOR PHYSICS. 3.0 Semester Hrs.
Bridges the gap between courses in fundamental nuclear physics and the practice of electrical power production using nuclear reactors. Review of nuclear constituents, forces, structure, energetics, decay and reactions; interaction of radiation with matter, detection of radiation; nuclear cross sections, neutron induced reactions including scattering, absorption, and fission; neutron diffusion, multiplication, criticality; simple reactor geometries and compositions; nuclear reactor kinetics and control; modeling and simulation of reactors. Prerequisite: PHGN422.

PHGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN601. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(I) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN602. ADVANCED GRADUATE SEMINAR. 1.0 Semester Hr.
(II) Ph.D. students will attend the weekly Physics Colloquium. Students will be responsible for presentations during this weekly seminar. See additional course registration instructions under Program Requirements above. 1 hour seminar; 1 semester hour.

PHGN608. ELECTROMAGNETIC THEORY II. 3.0 Semester Hrs.
Spherical, cylindrical, and guided waves; relativistic 4-dimensional formulation of electromagnetic theory. Prerequisite: PHGN507. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN612. MATHEMATICAL PHYSICS II. 3.0 Semester Hrs.
Continuation of PHGN511. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN623. NUCLEAR STRUCTURE AND REACTIONS. 3.0 Semester Hrs.
The fundamental physics principles and quantum mechanical models and methods underlying nuclear structure, transitions, and scattering reactions. Prerequisite: PHGN521. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN624. NUCLEAR ASTROPHYSICS. 3.0 Semester Hrs.
The physical principles and research methods used to understand nucleosynthesis and energy generation in the universe. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered on demand.

PHGN641. ADVANCED CONDENSED MATTER PHYSICS. 3.0 Semester Hrs.
Provides working graduate-level knowledge of applications of solid state physics and important models to crystalline and non-crystalline systems in two and three dimensions. Review of transport by Bloch electrons; computation, interpretation of band structures. Interacting electron gas and overview of density functional theory. Quantum theory of optical properties of condensed systems; Kramers-Kronig analysis, sum rules, spectroscopies. Response and correlation functions. Theoretical models for metal-insulator and localization transitions in 1, 2, 3 dimensions (e.g., Mott, Hubbard, Anderson, Peierls distortion). Boltzmann equation. Introduction to magnetism; spin waves. Phenomenology of soft condensed matter: order parameters, free energies. Conventional superconductivity. Prerequisites: PHGN440 or equivalent, PHGN520, PHGN530. 3 hours lecture; 3 semester hours.

PHGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

PHGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

PHGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SPACE RESOURCES (SPRS)

SPRS501. SPACE RESOURCES FUNDAMENTALS. 3.0 Semester Hrs.
(I, II) This course provides an overview of the space resources field, including the current knowledge of available resources in the Solar System, extraction and utilization systems under development, economic and technical feasibility studies, legal and policy issues, and space exploration architectures that may be enabled by utilizing extraterrestrial resources in the near future. The course will build broad knowledge and develop confidence in problem solving in the space resources field. Prerequisite: Working knowledge of physical sciences, engineering fields, or economics at an advanced undergraduate level, with basic numerical analysis skills using a programming language or spreadsheet calculations. 3 hours lecture; 3 semester hours.

SPRS502. SPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I, II) This course conveys the fundamentals of the systems engineering process as applied to large, complex space systems. It is intended for graduate students with various backgrounds. The students will become familiar with full scope of the systems engineering process from requirements definition, system design, system analysis through system verification. The process will be illustrated with real-world examples from current space systems with an emphasis on systems relevant to the development of space resources. Co-requisite: SPRS501. 3 hours lecture; 3 semester hours.

SPRS503. SPACE RESOURCES GRADUATE SEMINAR. 1.0 Semester Hr.
(I, II) The Space Resources Graduate Seminar will engage graduate students in the program with current research and developments related to space resources assessment, extraction, and utilization. The course, which will meet once a week, will provide students opportunities to engage with invited guest speakers who are industry, government, and academic leaders in the space resources field. Students will be asked to prepare a few short reports on research related to guest speaker seminars. Students will also prepare and deliver at least one technical presentation on their own work and/or that of others and lead a discussion on the topic of interest. This course will instill knowledge and confidence in the students to enable them to critique, articulate, and present concepts and relevant research and development in space resources. Co-requisite: SPRS501. 1 hour seminar; 1 semester hour.

SPRS591. SPACE RESOURCES DESIGN AND ANALYSIS I. 2.0 Semester Hrs.
(I, II) This course will provide graduate students in the program with directed team-based project learning by exploring the design, planning, and analysis of a mission, process, or systems for space resources assessment, extraction, and/or utilization. The course will meet formally twice a week for one hour and include a 10-15 minute discussion on relevant design aspects of space mission, processes, and/or systems. In this regard, it will build on content learned in the Space Resources Fundamental and Space Systems Engineering courses. Students will collaborate in multi-disciplinary teams of up to 5 students. Teams will be advised by the course instructor with significant industrial aerospace design experience and supported by faculty affiliated with the Space Resources program from relevant disciplines on campus. For teams with students in space resource economics, detailed economic analysis will be incorporated into those projects. Student teams will prepare a preliminary design, planning and analysis report early in the semester, one interim progress report, and a final report and project presentation. This course will guide the students and teach them good design and analysis practices and principles for missions and/or systems related to space resources. Co-requisites: SPRS501 and SPRS502. 2 hours lecture; 2 semester hours.

SPRS592. SPACE RESOURCES DESIGN AND ANALYSIS II. 3.0 Semester Hrs.
(I, II) The Space Resources Design and Analysis II course will provide graduate students in the MS-NT and Ph.D. degree programs in Space Resources with an independent design and analysis project. This project, which will be guided by the course instructor and a technical advisor, will enable the student to delve deeply into a particular system related to space resources prospecting, extraction, processing, and/or utilization. As much as possible, projects will be coordinated with industrial or government agency partners who are collaborating with the program. The course will involve weekly meetings with the course instructor and all students in the course where ideas are exchanged and progress discussed within the context of design and analysis principles learned in the pre-requisite course SPRS591. Students will be partnered with a faculty member affiliated with the Space Resources program. The student will prepare a final report and presentation to present to industry collaborators, space resources faculty, and other students in the course. The final report and/or presentation as appropriate will be converted to a journal or conference publication and/or presentation and resources from the program will support student costs for publishing and/or presenting the work. Prerequisite: SPRS591. 3 hours lecture; 3 semester hours.

SYSTEMS (SYGN)

SYGN501. RESEARCH SKILLS FOR GRADUATE STUDENTS. 1.0 Semester Hr.
(I, II) This course consists of class sessions and practical exercises. The content of the course is aimed at helping students acquire the skills needed for a career in research. The class sessions cover topics such as the choice of a research topic, making a work plan and executing that plan effectively, what to do when you are stuck, how to write a publication and choose a journal for publication, how to write proposals, the ethics of research, the academic career versus a career in industry, time-management, and a variety of other topics. The course is open to students with very different backgrounds; this ensures a rich and diverse intellectual environment. Prerequisite: None. 1 hour lecture; 1 semester hour.

SYGN502. INTRODUCTION TO RESEARCH ETHICS. 1.0 Semester Hr.
A five-week course that introduces students to the various components of responsible and research practices. Topics covered move from issues related to the planning of research through the conducting of research to the dissemination of research results. The course culminates with students writing and defending their ethics statements. 1 hour lecture/lab; 1 semester hour.

SYGN503. TOOLS FOR SUCCESS: INTEGRATING INTO THE MINES COMMUNITY. 1.0 Semester Hr.
(I, II) Designed for both incoming and experienced international graduate students who want to strengthen their professional skills for their degree programs and careers. Through engaging materials and conversation, students learn how to more confidently meet expectations, develop an effective professional relationship with their advisor and others on campus, strengthen communication skills, upgrade the quality and efficiency of their writing and presentations, and resolve conflict. Offers a relaxed, friendly space for students to explore questions regarding the cultural and academic transitions they are making and to share strategies for success. 1 hour lecture; 1 semester hour.

SYGN550. INTELLIGENT GEOSYSTEMS. 3.0 Semester Hrs.
Geosystems are natural or engineered earth structures, e.g., earth dam or levee, groundwater system, underground construction site, contaminated aquifer. An intelligent geosystem is one that can sense its environment, diagnose its condition/state, and provide decision support to improve the management, operation or objective of the geosystem. The goal of this course is to offer students background material in this interdisciplinary field. The course will consist of the following five modules: SmartGeo Overview, Sensing, Data Processing, Modeling, and Decision Support. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

SYGN555. SMARTGEO SEMINAR. 1.0 Semester Hr.
Geosystems are natural or engineered earth structures, e.g. earth dams or levees, groundwater systems, underground construction sites, and contaminated aquifers. An intelligent geosystem is one that can sense its environment, diagnose its condition/state, and provide decision support to improve the management, operation, or objective of the geosystem. The goal of this course is to introduce students to topics that are needed for them to be successful working in a multi-disciplinary field. The course will include training in leadership, multidisciplinary teams, policy and ethical issues, and a monthly technical seminar. Prerequisite/Corequisite: SYGN550. 1 hour lecture; 1 semester hour credit.

SYGN598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

SYGN600. COLLEGE TEACHING. 2.0 Semester Hrs.
This course is designed for graduate students planning careers in academia and focuses on principles of learning and teaching in a college setting; methods to foster and assess higher order thinking; and effective design, delivery and assessment of college courses. Prerequisite: None. 2 hours lecture; 2 semester hours.

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